STATE OF CONNECTICUT.

TWELFTH ANNUAL REPORT

OF THE

STORRS

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

1899.

PRINTED BY ORDER OF THE GENERAL ASSEMBLY.

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1900.

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The Station is located at Mansfield (P. O. Storrs), as a department of the Connecticut Agricultural College. The chemical and other more abstract research is carried out at Wesleyan University, Middletown, where the Director may be addressed.

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Report of the Executive Committee.

To His Excellency George E. Lounsbury,

Governor of Connecticut:

In accordance with the resolution of the General Assembly concerning the congressional appropriations to the Agricultural Experiment Stations, and an Act of the General Assembly approved March 19, 1895, relating to the publication of the Reports of the Storrs Agricultural Experiment Station, we have the honor to present herewith the Twelfth Annual Report of that Station, namely, that for the year 1899.

The accompanying report of the Treasurer gives the details of receipts and expenditures. We refer you to the report of the Director and his associates for a statement of the work accomplished during the past year. We are confident that the funds have been wisely expended, and that the work accomplished is such as will result in great benefit to our agricultural and other interests.

Respectfully submitted,

T. S. GOLD,
W. E. SIMONDS,
G. W. FLINT,
Executive Committee.

Report of the Treasurer

FOR THE FISCAL YEAR ENDING JUNE 30, 1899.

The following summary of receipts and expenditures, made out in accordance with the form recommended by the United States Department of Agriculture, includes, first, the Government appropriation of $7,500, and, secondly, the annual appropriation of $1,800 made by the State of Connecticut, together with various supplemental receipts. These accounts have been duly audited according to law, as is shown by the Auditors' certificates, copies of which are appended.

GOVERNMENT APPROPRIATION—RECEIPTS AND EXPENDITURES.

RECEIPTS.	
United States Treasury,	$7,500 00
EXPENDITURES.	
Salaries,	$3,199 76
Labor,	1,088 94
Publications,	326 08
Postage and stationery,	368 69
Freight and express,	85 14
Heat, light, and water,	458 94
Chemical supplies,	154 69
Seeds, plants, and sundry supplies,	154 37
Feeding stuffs,	264 64
Tools, implements, and machinery,	1 60
Furniture and fixtures,	543 15
Scientific apparatus,	516 07
Live stock,	40 44
Traveling expenses,	99 32
Contingent expenses,	10 00
Building and repairs,	188 17
Total,	$7,500 00

AUDITORS' CERTIFICATE.

This certifies that we have this day examined the accounts of Henry C. Miles, Treasurer of the Storrs College Experiment Station, for the fiscal year ending June 30, 1899, and have compared said accounts with the vouchers and find the same to be correct, showing receipts and expenditures both amounting to the equal sum of ($7,500) seven thousand five hundred dollars.

THEODORE S. GOLD,
W. E. SIMONDS,
Auditors of Connecticut Agricultural College.

HARTFORD, June 30, 1899.

STATE APPROPRIATION AND SUPPLEMENTAL RECEIPTS—RECEIPTS AND EXPENDITURES.

RECEIPTS.

State of Connecticut,	$1,800 00
Miscellaneous receipts,	1,174 32
Total,	$2,974 32

EXPENDITURES.

Salaries,	$1,399 62
Labor,	375 10
Publications,	17 67
Postage and stationery,	51 60
Freight and express,	17 56
Heat, light, and water, including electric power,	184 09
Chemical supplies,	168 05
Bacteriological investigations,	500 00
Seeds, plants, and sundry supplies,	34 48
Furniture and fixtures,	51 50
Scientific apparatus,	170 43
Live stock,	35
Traveling expenses,	3 87
Total,	$2,974 32

HENRY C. MILES, *Treasurer.*

AUDITORS' CERTIFICATES.

This certifies that we have this day examined the accounts of Henry C. Miles, Treasurer of the Storrs College Experiment Station, "Investigation of food economy," for the fiscal year ending June 30, 1899, and have compared the said accounts with the vouchers and find the same to be correct, showing receipts and expenditures both amounting to the equal sum of ($1,800) eighteen hundred dollars.

THEODORE S. GOLD,
W. E. SIMONDS,
Auditors of Connecticut Agricultural College.

HARTFORD, June 30, 1899.

This certifies that we have examined this day the miscellaneous accounts of Henry C. Miles, Treasurer of the Storrs College Experiment Station for the fiscal year ending June 30, 1899, and have compared said accounts with the vouchers and find the same to be correct, showing receipts and expenditures both amounting to the equal sum of ($1,174.32) eleven hundred and seventy-four 32-100 dollars.

THEODORE S. GOLD,
W. E. SIMONDS,
Auditors of Connecticut Agricultural College.

HARTFORD, June 30, 1899.

Report of the Director for the Year 1899.

During the year 1899 the work of the Station has been along lines similar to those followed for several years past. It includes experiments on the effects of fertilizers upon the growth and composition of plants, studies of dairy bacteriology and of bovine tuberculosis, and investigations upon the food and nutrition of man. The digestion experiments with sheep which have been carried on for a number of years have been discontinued. Studies of milk production by cows, carried out with the college and private herds, by Prof. C. L. Beach, of the Connecticut Agricultural College, were reported in Bulletin 20 of the Station.

METEOROLOGICAL OBSERVATIONS.

The usual observations of temperature, barometric pressure, wind velocity, humidity and precipitation have been made at Storrs. In addition, records of rainfall during the growing season have been made in other places by farmers who have coöperated with the Station.

EXPERIMENTS ON THE EFFECT OF FERTILIZERS UPON THE YIELD AND THE COMPOSITION OF CROPS.

Plot experiments.—From the time of its establishment the Station has been engaged in experiments for testing the effects of fertilizers upon the amounts and composition of the crops produced. These have been made principally with grasses, grains, and legumes. Several series have been carried out continuously on the same land year after year. The larger number have been made in the field, but some, with grasses, have been conducted on a smaller scale in the experimental garden. The results have been reported from year to year. During the past year these experiments have been made with corn, cow peas, soy beans, and various species of grasses, in both the field and in the garden.

In the Report of the Station for 1898 a detailed account was given of the results of these experiments, especially in their bearing upon the effect of nitrogenous fertilizers. It has long been known that nitrogenous fertilizers increase the yield of grasses and cereals, but have comparatively little effect upon the yield of legumes. The most important result of these experiments is to show that the nitrogenous fertilizers increase also the proportion of nitrogen in the grasses and cereals, although they have but very little effect upon the composition of the legumes. This principle, which has hitherto been but little understood, is of much importance to the farmer.

Pot experiments.—Experiments for the study of the effects of nitrogenous fertilizers upon the proportion of nitrogen in the plants have been made on a small scale in such a way that moisture and other external influences might be more completely under control. In these experiments the plants are grown in large pots by the use of the same kinds of nitrogenous and other fertilizers as are used in the plot experiments, the total produce being weighed and taken for analysis. The details of these experiments are withheld from publication until more data shall have accumulated.

DAIRY BACTERIOLOGY.

For a considerable number of years Prof. Conn and his assistants have carried on investigations upon dairy bacteriology. One of the special objects of the latter work has been to get information concerning the species of bacteria that are more common in Connecticut dairies, their sources, and especially their effects upon milk and cream and upon butter made from the cream ripened under their influence. For several years past Prof. Conn has been assisted in this work by Mr. W. M. Esten, who has devoted much time to these investigations and has made an especial study of the organism *B. acidi lactici*, which is the most common cause of the souring of milk, and which he isolated in 1896. These investigations have been continued during the past year, special attention being devoted, as previously, to the ripening of cream and to the bacteria concerned in the process.

The results of the investigations by Prof. Conn and his associates have been published year by year in the Reports and

Bulletins of the Station. With the progress of the inquiries and the increase in the number of species isolated, it has been found necessary to devise a method of classification in order to make it easier to determine whether any particular organism which may be isolated is identical with some one already found or is a new species. In the present Report Prof. Conn discusses a method which he has developed for use in his own laboratory, and classifies according to it the species which he has isolated there. This method of classification has proved so useful that Prof. Conn has given it herewith in considerable detail, in the hope that it may prove useful in establishing a means by which American bacteriologists can compare their results.

BOVINE TUBERCULOSIS.

The experiments with tuberculous cows and with their milk for feeding calves, which were begun in 1896, have been continued during the past year. The present Report gives a statement concerning the condition of the cows and details of the experiments for the year 1899. These studies are being continued.

ANALYSIS OF FOODS, FEEDING STUFFS, ETC.

In connection with the inquiries of the Station a large number of chemical analyses are required. During the past year these have included analyses of samples of crops grown in the tests with fertilizers, and of foods and other materials used in the metabolism experiments with man.

In addition to the chemical analyses of the various foods, feeding stuffs, etc., the heats of combustion of these materials, which are used in determining their fuel values, have been determined by the use of the bomb calorimeter.

FOOD AND NUTRITION OF MAN.

Investigations upon human nutrition have been carried on during the past year as usual. These are conducted in coöperation with the U. S. Department of Agriculture, which defrays a considerable share of the expense. In this way much more extensive and accurate inquiries are made than would otherwise be possible. The lines of research during the past year have been chiefly metabolism experiments with a

man in the respiration calorimeter, studies of the digestibility of mixed diets, and studies of actual dietaries. Summaries of the work done and statements of the most important results obtained and conclusions reached, have been given in publications of the Station for the past few years and may be found in this Report. The full details, which are too voluminous for publication by the Station, and are of such general interest as to call for wider distribution than it could give them, are published by the Department of Agriculture. These investigations form a part of a more general inquiry which is authorized by Congress and is carried out in different parts of the country under the authority of the Secretary of Agriculture, who has placed them in charge of the Director of this Station.

Dietary studies.—The studies of actual food consumption of groups of people and of individuals form as in the past one of the important lines of inquiry of the Station. During the past eight years the results of over 350 dietary studies in the United States have been reported, the majority of which were conducted by experiment stations and other institutions in coöperation with the U. S. Department of Agriculture as a part of the general inquiry just mentioned. Of these studies about fifty were carried out by this Station. The work of the past year includes the study of the actual food consumption at two of the buildings of the Connecticut Hospital for the Insane during one week, and several dietaries of families and individuals for various periods.

Digestion experiments.—Twelve experiments upon the digestibility of food by man were made during the past year. The results obtained in these and similar investigations elsewhere, together with those obtained from analyses of food materials and from determinations of heats of combustion by use of the bomb calorimeter, have been utilized in deriving the data for the availability and the nutritive value of American food materials which are summarized in one of the articles of this Report.

Metabolism experiments. — Eleven metabolism experiments were carried on during the past year, the details of which will appear in Bulletins of the U. S. Department of Agriculture. Some of the results of the work are given in the present Report.

Such research is elaborate, time consuming and costly, but the results are already such as to give great encouragement, and it is my belief that no work which the Station has attempted is producing or would produce results so valuable, whether viewed from the standpoint of pure science or that of practical utility, as this and kindred lines of investigation.

Respiration calorimeter.—The metabolism experiments just referred to have been made by the use of the respiration calorimeter. Concerning the nutrition investigations in general and this apparatus in particular, the following statement may not be out of place here. It is taken from Bulletin 80, of the Office of Experiment Stations of the U. S. Department of Agriculture, a volume which was prepared to accompany the exhibit of American Agricultural Experiment Stations at the Paris Exposition of 1900:

"From the scientific standpoint, the most noteworthy feature of these inquiries is found in the researches with the Atwater–Rosa respiration calorimeter, by means of which the study of the application of the laws of the conservation of matter and of energy in the human body are being carried out with a completeness not previously attained. Indications of the value of this apparatus and method of inquiry are already apparent in the fact that an apparatus on the same general plan, but large enough for experiments with domestic animals, is already in process of construction at the Experiment Station of the State College of Pennsylvania, under the direction of Prof. H. P. Armsby, and in coöperation with the Bureau of Animal Industry of this Department. The Prussian Government has provided means for the construction of a similar apparatus for the Institute of Animal Physiology at Bonn, under Prof. Hagemann. An appropriation, under government authorization, has also been made for the construction of a like apparatus in connection with the Institute of Animal Physiology at Budapest, under Professor Tangl."

EXHIBIT OF THE STATION AT THE PARIS EXPOSITION.

By invitation of the Committee of the Association of American Agricultural Colleges and Experiment Stations on a Collective Station Exhibit at the Paris Exhibition, a cabinet of forty-eight cultures of bacteria, isolated from various dairy products, and prepared by Prof. Conn, a bomb calorimeter with all its accessory apparatus, and a model of the respiration calorimeter were contributed to this general Experiment Station exhibit. The selection of these subjects was in accordance with the suggestion of the committee mentioned above,

whose object was to exhibit at Paris such things as would best exemplify the most valuable scientific as well as practical work of the experiment stations of the United States.

PUBLICATIONS.

Two Bulletins have been issued during the past year: Bulletin No. 20, "A Study of Dairy Cows," by Prof. C. L. Beach, of the Connecticut Agricultural College, and Bulletin No. 21, "The Ripening of Cream," by Prof. H. W. Conn. Other Bulletins are now in preparation and will be issued from time to time. These are printed in numbers sufficient to supply the entire mailing list of the Station, whereas the number of Reports issued will be somewhat smaller than in previous years. This change, which it is believed will prove very advantageous, has been made practicable by the Act of the last General Assembly, which permits the publication of the more technical details in the Annual Report for a permanent record and for the especial use of those interested in such matters, while it also provides for the printing of popular Bulletins of a more practical character in larger editions for more general distribution.

W. O. ATWATER,
Director.

CLASSIFICATION OF DAIRY BACTERIA.

BY H. W. CONN.

COLLECTION OF THE BACTERIA.

For the last ten years, in which the work upon dairy bacteriology has been carried on for this Station, I have been gradually collecting from the dairy products of the vicinity a variety of forms of bacteria. These have been obtained from milk and cream and occasionally from butter. During that time a very large number of different cultures have been isolated from these dairy products, and have been studied in the laboratory by bacteriological methods with more or less completeness. Of the many hundreds thus collected, large numbers of course have proved to be duplicates. As fast, however, as it became apparent that any particular form isolated and studied was distinct from those previously characterized, the bacteriological characteristics of the new variety were carefully detailed and the form was entered in a list by number, together with the characteristics as they were determined. In this way there has accumulated a list of over 200 different types of bacteria which have been regarded as more or less distinct from each other. It may be assumed that this list contains probably all of the common species of bacteria which are likely to be found in dairies of this vicinity. Of this long list many of course have been found to be very commonly, some indeed almost universally, present in milk. Others are more uncommon, being found only a few times, and many indeed have been isolated only a single time and must therefore be regarded as purely accidental. It has been found, as would be expected, that the species of bacteria in a sample of milk vary somewhat with the locality from which the milk is obtained, and also with the season of the year in which the examination is made. A few forms of organisms are so widely distributed as to be almost universal, both as to locality and as to season.

Of the bacteria in my list there are quite a number that have not been described with sufficient accuracy to make the description of any considerable value. This is true especially of some

of the earlier varieties that were isolated before the methods of description were sufficiently worked out; and it is also true of some of the later ones which were by accident lost before a complete description was obtained. Moreover, during the period in which these experiments have been going on the methods of bacteriological work and description have been quite materially changed, and it is now considered essential to determine certain characteristics which in early years were not much attended to. The result is that the descriptions given beyond of the different bacteria are of varying value. No one can be more fully aware of the incompleteness of some of these descriptions than myself, and for this reason a considerable number of the bacteria in the list which I have collected will be left out from the following classifications because the descriptions are too incomplete to be of any particular value.

NEED OF CLASSIFICATION OF BACTERIA.

As the list of dairy bacteria in my hands has thus been increased, it has been found more and more necessary that some kind of classification and grouping of these different bacteria should be devised. When the number reaches into the scores it is a matter of very great difficulty to determine whether the new culture isolated from milk is really new or is identical with some of the forms previously studied, and it becomes therefore absolutely necessary that some simple means of grouping the different bacteria should be obtained to make this determination possible. During the past few years I have gradually developed a method of grouping these bacteria which has proved extremely useful in my laboratory and has very greatly simplified the problem of the further study of new varieties isolated.

Inasmuch as it has proved so useful in the determination of the forms found here, I have thought it not unwise definitely to formulate the method of grouping which has been used, and to publish along with it the descriptions of all of the more important of the varieties of bacteria which have been isolated here. There are at the present time a number of American bacteriologists working upon dairy bacteriology, and it is eminently desirable that they should be able to compare their results with each other. As long as the species found by one bacteriologist are described only in private notes, they cannot

of course be compared with those found by another, and the work of the different observers in different parts of the country cannot be brought into relation. It is certainly time that our dairy bacteriologists should begin to compare results. For the purpose of making a beginning in this direction, the following classifications and descriptions of bacteria have been put together and are now published. It is hoped that it may serve to enable the different dairy bacteriologists to compare the species of bacteria in one locality with those in another, and thus may aid in simplifying the problem of the species of dairy bacteria. Hitherto there has been nothing of this sort published in this country, nor indeed in Europe. Isolated descriptions of a few dairy bacteria have been published in one place and another, but no attempt has been made to get together under one list the types of bacteria which are found in dairy products. The water bacteria have been much more carefully studied and classified; and it is clearly a matter of importance that the dairy bacteria should in a similar way be brought under more or less distinct classification. The present list will therefore serve as a start in this direction.

METHOD OF CLASSIFICATION.

No one can be more fully aware of the incompleteness of the following list than I am myself. Strictly anaerobic species I have not yet studied, nor have I as yet made any study of the spore forming species which remain in milk after boiling. Some of the species are imperfectly described. Doubtless some of my species should be divided, and perhaps others that I have regarded as separate will subsequently be united into one. But all pioneer attempts at classifying bacteria must be open to criticism. It is my hope that this classification may be the beginning of a work which shall be slowly perfected, and may be at all events of use as a point of departure for the adoption of better plans in future. If it shall serve as a means of bringing together the work of American dairy bacteriologists its purpose will be accomplished.

Every one who has had anything to do with the descriptions of bacteria has been impressed with the difficulty of following through those given in the ordinary way and comparing them with each other. This is due partly to the great detail which is given in some cases and to the lack of detail in others. In

many of these descriptions nonessential features are given with great detail, and the whole becomes immensely confusing. It has seemed to me that the method adopted by Fuller and Johnson in a recent publication on water bacteria* marks a very decided advance in our method of arranging the characteristics of bacteria. They have devised a scheme whereby all of the important characteristics of a given species of bacteria may be briefly indicated by positive or negative signs, so that, by the proper arrangement of tables, it is possible by the use of a few of these signs to give in a very brief compass all of the important characteristics of the organisms to be described. The advantages of this scheme are manifold. In the first place it avoids the needless confusion of details which is so likely to arise from the verbose descriptions which may be given. In the second place it makes possible a direct comparison of species with each other, and enables one to determine at a glance whether two forms are in agreement so far as regards their chief characteristics. If then further details be given elsewhere, with more careful descriptions, the task of determining whether a new variety is identical with one already described is an easy one. The success of this method as applied to water bacteria has led me to adopt the same in the description and classification of the dairy bacteria, and the tables in the following pages are therefore based upon the same principle as those which have been used by Fuller and Johnson in their classification of water bacteria.

In these tables, however, I have found it necessary to adapt the plan to the descriptions which I have in my possession, and consequently to change the character of the table somewhat. In the study of dairy bacteria certain characteristics have been inevitably regarded as of more importance than others; and in the descriptions of the bacteria which I have been accumulating some factors, particularly those in connection with the action of the bacteria upon milk, have been studied in more detail than would be possible to indicate in the table of Fuller and Johnson. On the other hand, some of the characteristics which they have included in the study of water bacteria have not been determined at all, or only incidentally, in the case of the bacteria studied here. This is to be regretted, since it is eminently desirable that the different

* Jour. of Exp. Med., 1899.

bacteria should be comparable with each other. It is, however, at present unavoidable, because most of these species have not been preserved in culture in the laboratory, and it is now impossible to determine the characteristics which have not hitherto been made out. For these reasons the tables which I have been obliged to make out and to use differ in some details from those of Fuller and Johnson. I have, however, followed them as closely as possible.

SOURCES OF THE SPECIES.

A word as to the sources of the different species of bacteria which are here described. All have been obtained from dairy products. A majority of them have come from cream either from neighboring creameries or from private dairies, some being obtained from ripened cream, others from unripened cream. Some of them have been obtained from milk as delivered in Middletown by milkmen. Some have been obtained from the milk after it has stood in the pantries of private houses. Some of the species have been obtained directly from milk as drawn from the teats of the cow into sterilized vessels, others again from the dust which falls into the milk pails during the milking. Two of these species have been obtained from some samples of special milk which had been sent in cans from Uruguay; and some of the species have been obtained from samples of milk that were sent to Middletown from a large number of States in the Union, ranging from Maine to California. All, however, are strictly dairy organisms, being found in milk or its products.

METHOD OF ISOLATION AND STUDY.

The method of isolation and study requires little description, inasmuch as it has been, in general, that commonly used in bacteriological study. For the isolation of the bacteria from the milk ordinary gelatin has been used. In most of the early years the gelatin was made in the ordinary way, but in recent years it has been found that a much more satisfactory result is obtained if there is added to the gelatin three per cent. of milk sugar. The reason for this is manifest. Milk always contains a considerable portion of milk sugar. Naturally, therefore, it is to be expected that the typical dairy bacteria will grow much more rapidly in gelatin provided with milk sugar. Indeed, some

of the characteristic species are isolated with great difficulty from cream by the use of ordinary gelatin, but are found with the greatest of readiness by the use of sugar gelatin. Practically also it has been found extremely useful to employ for this purpose only gelatin which has been rendered blue with litmus solution, as this makes it possible readily to distinguish the acid organisms from those that do not produce acids. It has been found that one species of bacterium which is par excellence a dairy species, namely *B. acidi lactici*, No. 206, produces in such gelatin a colony which is most readily distinguished from any other species of bacteria, and this of course makes it extremely convenient for use.

After isolation of the bacteria they have been purified by replating in the customary manner, and then inoculated into the ordinary media for the purpose of determining their characteristics, which have been obtained as usual. Special attention, however, has always been given to the effect of the organisms upon milk at ordinary room temperature and at higher temperatures. In many cases also the action of the organisms upon sterilized cream has been determined, and in a considerable number of the cases the influence of the organisms upon the character of the butter obtained from cream ripened by means of them has been made out.

Unfortunately, the use of the fermentation tube has not been adopted so widely as would be desired. In the study of some species the fermentation tube has been used, but in the majority of cases it has not. In the work that is done now it is used in all cases, but in many of the descriptions which have been given in past years this important test was omitted. For this reason the production of gas in glucose bouillon has not been determined in many cases. In determining the characteristics of these bacteria no attempt has been made to determine their action upon nitrites or the production of indol, nor has any attempt to determine pathogenic characteristics been made. These features have not yet been regarded as of significance enough in the study of dairy bacteria for dairy purposes to warrant the time which would be taken in determining them.

GROUPING THE BACTERIA.

In dividing the dairy bacteria into groups I have tried so far as possible to follow the methods already adopted, and have

used as the foundation of my grouping that of Flügge given in the last edition of his *Die Microörganismen*. This grouping, as will be seen below, is based partly upon the power of producing pigment and partly upon morphological data. This arrangement is quite similar to that which has been adopted by Fuller and Johnson, and is easily compared with that which has been adopted by Chester in his valuable study of the classification of bacteria. As I have arranged these groups it results that in some cases there are placed together under one table the two genera which Migula has distinguished as *Bacillus* and *Bacterium*. According to Migula's classification a distinction between these two genera is based upon the formation of spores. The genus *Bacillus* produces spores, while the genus *Bacterium* does not produce spores. By the method of grouping which I have adopted, it has resulted that in groups IV. and VII. both of the genera *Bacillus* and *Bacterium* are included. This confusion, however, is not a serious one, since it involves only a few organisms. The grouping that has been adopted in the following pages is one which I have found to be the easiest to use in laboratory practice. The groups which I have recognized are as follows:

GROUP I. *Fluorescent bacteria.*
II. *All red chromogenic forms.*
III. *All orange chromogenic forms.*
IV. *All lemon yellow chromogenic forms.*
V. *All non-liquefying micrococci not included in II., III., and IV.*
VI. *All liquefying micrococci not included in II., III., and IV.*
VII. *All non-liquefying rods which are not chromogenic. These are mostly of the species Bacterium, but the table includes two of the genus Bacillus.*
VIII. *All liquefying Bacteria without spores.*
IX. *All liquefying Bacilli with spores no larger than the rods.*
X. *All liquefying Bacilli with large spores causing the rods to be swollen at the time of sporulation.*

NAMING THE SPECIES.

In regard to the question of naming the species described, I have been somewhat at a loss as to the best method of procedure. Some of the species which are described are unquestionably entirely new and are very distinctly characterized. Others are very obscure in their diagnostic character, so much so that it has been difficult or impossible to give characters which very clearly define them. In these cases I have been

uncertain whether I was dealing with wholly new species or not. Some of the species described are very abundant and are found very frequently in dairy products, while others are rare, being found only once or twice. In my original laboratory notes each of these species has been entered by number. But it has seemed to me wisest in the following pages to apply names to such species as are clearly distinct and new. I have looked through the literature of systematic bacteria as carefully as possible, and wherever I could do so I have identified the species I have found with those described elsewhere. This, however, has not been possible in a majority of cases. It must be regarded as doubtful whether the identification of species found in milk with those found in water, soil, and air is accurate, and when the attempt is made to identify American species with those of Europe the uncertainty becomes very great. A few well marked species may be thus readily recognized, but for most species we must, in the present condition of bacteriology, recognize that any identifications of American dairy bacteria with bacteria from other sources and localities is very uncertain. For the most part the dairy bacteria must at present be considered by themselves. Where I have been able to class my species with those elsewhere described, the classification has been indicated by applying to the organism here described the name of the species with which it has been identified.

In regard to the rest of the species which cannot be identified with any described species, I have adopted the following plan. Wherever the species in question is an extremely common one or one that is very easily described and recognized from description, I have given it a specific name. In using these names I have in most cases added the word *lactis* for the purpose of indicating the fact that the organism in question is of a species found in milk. In the following pages, therefore, where a new name has been applied to a described organism this indicates either that it is a very abundant dairy organism or that it is one whose characters are so distinct as to indicate clearly that it differs from any other described species, and moreover so distinct that it can easily be recognized from the description. Where the organism in question, however, is found only rarely in dairy products and has characteristics so obscure as to make

it difficult to define it with accuracy, I have simply retained the original number by which this species has been entered in my laboratory notes. It is hoped that further study in future years may enable me to determine more accurately whether the species should be subsequently kept isolated and given specific names or whether they may eventually be merged into some of the other more common types.

METHOD OF TABULATION.

In the use of the tables the following methods have been adopted. At the top of the table in parallel columns are given certain characteristics which are indicated for each organism in the proper column by the sign + or —. The sign + indicates always that the species possesses the characteristic in question, the sign — that it does not possess the characteristic in question. In some places the sign ± has been inserted, which indicates that the characteristic in question is doubtful. For example, under the column headed "Diameter greater than 1μ" the ± means the diameter is practically 1μ. In the column referring to the reaction of milk, the ± sign indicates that the reaction is unchanged or is amphoteric. The other places where the ± sign is used explain themselves. In the use of this table the word bacillus merely refers to the fact that the organism is a rod rather than a coccus, and it does not mean that the organism is a bacillus in the sense of Migula's classification.

The tables when thus filled out give in a brief compass the chief diagnostic characters of the different species of bacteria. But these are not sufficient to give a complete description. There is therefore given in the pages following the table, under the proper numbers and names, such description of diagnostic characters as may be needed, in addition to those inserted in the tables, for the proper diagnosis of the species. By the use of the tables and these descriptions together each species is described as fully as possible from the data which are in my possession. These tables will be found extremely simple to use if one has a species of bacterium which he wishes to identify with those described. My method is as follows: I make a "trial slip" giving the characters included in the tables. Upon this slip I enter the characteristics of the species being studied with the + and — signs in spaces corresponding to

the columns in the tables. Then by moving the trial slip up and down the table it is possible to determine at a glance whether it agrees with any of the described species. If it is found that the characteristics agree practically with those of any species given in these tables, reference to the descriptions following will give further details and will make identification in most cases a simple matter. The whole comparison takes only a very few minutes and is a great saving of time over the old method of comparing long detailed descriptions.

THE CHIEF DAIRY SPECIES.

It is necessary to give here a brief statement concerning the bacteria which are to be regarded as the distinctive dairy organisms of this region. Although the number of species found in dairy products as seen by the following pages is large, the number of those which are found with very great uniformity in dairy products is small. Indeed, as the result of my experiments I have concluded that the dairy organisms of this region are chiefly of four species. Strictly speaking, it is probably more correct to say three groups of closely related bacteria rather than four single species. They are as follows:

The most abundant of our dairy organisms is No. 206, which is the *B. acidi lactici* (Esten). As already mentioned in a previous publication,* it is almost universally found in samples of milk or cream. This appears to be true not only of milk and cream in this region but of milk from a very wide territory. Samples of milk that have been sent us from a large number of States have in almost all cases shown the presence of this organism in abundance. In sour milk it is almost always present. In all samples of ripened cream which we have studied it has been found to be by far the most abundant species. In most samples of ripened cream this No. 206 forms over 75 per cent. of the bacteria present, and sometimes over 90 per cent.

The source of this organism in our milk has been a matter of some little interest, and has been studied by experiment in the last few months. Its almost universal presence in milk, together with the markedly anaerobic character, would seem to indicate that it probably comes from the milk ducts. This

* See Report of this Station for 1896.

conclusion has not been borne out by the direct studies of bacteria in the milk ducts. Our recent experiments seem rather to point to the conclusion that this organism comes from external contaminations. When we have collected samples from large numbers of cows, drawing the milk directly from the teats into sterilized vessels with little or no chance for contamination, it has been found that milk thus obtained only in very rare cases contains the organism No. 206. In the experiments, which now number over 200 and involve 75 well kept cows, there have been only five instances where such milk contained this organism, and the cows concerned in these five cases did not show the same result with a second test. The milk obtained directly from the cows in this way contained many species, commonly including liquefying bacteria, but not this common lactic species. When, however, the milk is drawn from the cow into sterilized vessels with a more widely open mouth, the organism in question has been found in most cases to be present, and becomes abundant in a few hours. This indicates that the *B. acidi lactici* should be regarded as an organism which comes from external contamination, and is not a normal inhabitant of the milk duct. On the other hand, up to the present time I have not succeeded in finding the organism in question present in any considerable numbers in gelatin plates which have been exposed to the air underneath the cow during the milking process. My present belief is that this organism is not a normal inhabitant of the milk duct, but commonly is derived from external sources, and is practically always present in the milk vessels into which the milk is drawn.

Next in abundance to the organism just described is No. 202. This may perhaps be a variety of the last, but it differs from it in being more markedly anaerobic, and in producing a colony in gelatin which is extremely minute and indeed invisible to the naked eye, whereas No. 206 produces a good sized colony. This is also very abundant in nearly all samples of sour milk or cream, although the numbers are much less than those of the last species. This organism I have not been able to find in the milk ducts any more than the last, and I regard it also as being derived from external contamination.

These two species undoubtedly belong together, not only from their morphological similarity and their general likeness

in growth upon various media, but also from their action on milk. They certainly represent a type of dairy organisms common everywhere. Many of the lactic organisms hitherto described by different bacteriologists clearly belong to this type, although slight differences in described characteristics perhaps indicate different varieties. This is true of the *Bacterium acidi lactici* of Günther and Thierfelder, *Bacterium lactis acidi* of Leichmann, *Bacillus XIX.* of Adametz, *Bacillus a.* of v. Freudenreich, *M. acidi laevolacidi* and *B. acidi laevolactici* of Leichmann and several of the types described by Storch. The pure culture used in cream ripening and put on the market by Hansen is a culture of one of this type of lactic organisms, and the same is true of the pure cultures of Witte and Barnekow. All of these organisms agree very closely in general characters and are doubtless closely related. In this region this type, represented by No. 206 and No. 202, is the most abundant milk bacterium, at least in milk obtained in the ordinary manner and allowed to stand for several hours before testing.

The next most important dairy species in this vicinity is No. 208, which I have regarded as identical with *B. lactis aerogenes.* This is found almost universally, although never in very great numbers. The organisms included under this number, however, have shown very wide variations, and it is quite possible that a number of distinct types are here included. At all events, it is quite certain that if all these forms are to be regarded as one species, several quite distinct varieties must be recognized among them. The distinctive characteristics of these species are, (1) the intense acid that the colonies produce in litmus gelatin; (2) the abundance of gas which is developed when they grow in milk sugar bouillon or in milk; (3) the uncertainty as to their power of curdling milk, this occurring commonly at high temperatures though not commonly at room temperatures; and (4) the distinctive odor of sour milk which is found in milk that has been curdled by means of them. *B. acidi lactici*, I. and II., Nos. 206 and 202, although they curdle milk with the production of lactic acid, do not give rise to the typical sour milk odor, and neither of them develop any trace of gas in the milk. I am therefore convinced that the ordinary souring of milk is produced in part by the action of this No. 208, and that typical sour milk, with its tendency to

fragmentation and its sour odor, is never developed unless some of the organisms included in my No. 208 species are present. Ordinary sour milk, according to my observations, is produced by these three organisms, and probably in the spontaneous souring of milk all three are present.

I am convinced that here also the various bacteria which I have included under No. 208 do not represent a single bacterium, but rather a group of allied varieties, and as a group represent a most important dairy organism. In looking through the literature upon dairy bacteria, it appears to me that many of the lactic organisms that have been described by different observers belong to this group. The original *B. acidi lactici* of Hueppe apparently belonged here. Here, too, probably must be placed *Bacterium lactis acidi*, Marpmann, *Bacillus lactis acidi*, Marpmann, *Bacillus acidi lactici*, I. and II., of Grotenfelt, *No. 8* of Eckles, and doubtless several others. In the pure cultures used for cream ripening in European countries, known as the culture of Lorenz, the organisms appear to belong to this same type. The two forms recently isolated from Edam cheese by Leichmann and Bazarewski and called *Bacterium caesi*, I. and II., also belong to this series. It is quite unlikely that these different organisms are the same, although their morphological and cultural characters in general accord. All of these facts indicate that in the species which I have at present called *Bacillus lactis aerogenes* there are grouped together a number of types with great similarity, but with at least different physiological characters.

The third type of bacteria which I have found so abundant as to call it a distinctive dairy bacterium of this region is my *M. lactis varians*, No. 113. This has been sufficiently described elsewhere, and as already mentioned is a very highly variable Micrococcus both as to chromogenic powers and power of liquefying gelatin. This species is common in fresh milk and probably exists in the milk ducts. It is commonly overgrown by the lactic organisms and is less common in old milk. It is by no means universally found and may be only a local species.

Several other species in my list are quite common in milk, but I think that these four must be regarded as the chief dairy bacteria of this region.

CLASSIFICATION OF DAIRY BACTERIA.

TABLE I.

Name and Number.	Morphology. Bacillus.	Coccus.	Diam. greater than 1μ.	Motile.	Uniting in chains.	Spores.	Cultural Features. Nutrient broth tube. Turbidity.	Scum.	Sediment.	Nutrient agar tube. Dull.	Wrinkled.	Gelatin plate. Characteristic.	Proteus-like.	Moss-like.	Gelatin stab. Liquefies.	Deep funnel.	Needle growth.	Surface g'wth.	Gas produced.	Potato tube. Visible.	Luxuriant.	Fermentation tube. Growth in closed arms.	Biochemical Features. Grows at body temperature.	Facultative anaerobic.	Milk. Curdles.	Acid.	Alkaline.	Digests.	Slimy.	Strong odor.	Chromogenesis.	Fluoresence.	Gas production.
GROUP I. Fluorescent Bacteria.																																	
No. 31. B. fluorescens liquefaciens,	+	—	—	+	+	—	+	+	+	—	—	+	—	—	+	+	..	..	—	+	+	..	—	—	+	—	+	+	—	+	—	+	—
21. B. fluorescens schuylkilliensis,	+	—	—	+	+	—	+	+	+	—	—	+	—	—	+	—	..	..	—	+	+	..	+	—	+	—	+	+	—	+	—	+	—
128. B. fluorescens minutissemus,	+	—	—	+	—	—	+	+	+	—	—	—	—	—	+	—	..	..	—	+	+	..	+	..	+	—	+	—	—	—	—	+	—
5. B. viscosus,	+	—	±	+	—	—	—	+	—	+	—	—	—	—	+	+	..	..	—	+	+	—	—	—	+	—	+	+	+	—	—	+	—
82. } B. fluorescens non liquefaciens.	+	—	—	+	+	—	+	+	+	—	—	+	—	—	—	..	±	+	—	+	+	..	+	—	—	—	—	—	—	—	—	+	..
90. } Flügge,	+	—	—	+	—	—	+	+	+	—	—	—	—	—	—	..	±	+	—	+	+	..	+	—	—	—	—	—	—	—	—	+	..
(See also Nos. 126 and 66, Group VII.)																																	
GROUP II. Chromogenic type. Red.																																	
No. 209. B. prodigiosus,	+	—	—	+	—	—	+	+	+	—	—	+	—	—	+	—	..	..	—	+	+	+	+	+	+	—	+	+	—	—	red	—	..
62. M. rubidus lactis,	—	+	±	—	—	—	+	—	+	—	—	+	—	—	+	+	..	..	—	+	+	..	+	..	—	—	±	+	—	—	red	—	..
42. M. rosaceus lactis,	—	+	—	—	—	—	+	—	+	+	—	+	—	—	—	..	±	—	—	+	+	..	+	—	—	—	+	—	+	—	pink	—	..
115. B. ruber lactis,	+	—	—	—	+	—	—	—	+	—	+	—	—	—	+	—	..	..	—	+	+	..	+	+	+	—	+	+	—	—	pink	..	..
151,	+	—	—	+	—	—	+	—	—	—	—	+	—	—	+	—	..	..	—	+	+	..	—	+	+	—	+	+	—	—	pink	—	—

GROUP III.

Chromogenic type. (Orange.) Micrococci and Bacteria.

No. 188.* M. aureus lactis,	—	+	—	—	—	—	+	+	+	+	—	—	—	—	+	—	..	..	—	+	+	..	+	..	+	—	+	+	—	—	o-y	—	—
103.* B. aureus minutissimus,	+	—	—	+	+	—	+	+	+	—	—	+	—	—	+	+	..	..	—	+	+	..	—	—	—	—	+	—	+	—	o	—	..
113.* M. varians lactis,	—	+	±	—	—	—	+	—	+	+	—	+	—	—	+	—	..	..	—	+	+	..	+	±	+	—	±	—	—	—	o-w	—	—
104.† M. varians lactis,	—	+	±	—	—	—	+	—	+	+	—	—	—	—	—	..	+	+	—	+	+	..	+	±	—	—	±	—	—	—	o-w	—	—
159,† - - -	+	—	—	+	—	—	+	—	+	—	—	+	—	—	—	..	+	+	—	+	+	..	+	—	—	—	—	—	—	—	o	—	..
141,† - - -	+	—	—	—	—	—	+	—	+	—	—	—	—	—	—	..	+	+	—	—	—	..	+	+	—	—	—	—	—	—	o-y	—	..
162,† - - -	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	..	+	+	—	+	+	..	+	—	—	—	—	—	—	—	o-y	—	..
169,† - - -	+	—	—	+	—	—	—	+	+	—	—	+	—	—	—	..	+	+	—	+	+	..	+	—	—	—	+	—	—	—	o	—	..
170.† B. aureus acidi,	+	—	—	+	—	—	+	—	—	—	—	+	—	—	—	..	+	+	+	+	+	..	+	—	+	+	—	—	—	—	o	—	..
205.† } B. aureus lactis I.,	+	—	—	+	—	—	+	+	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	—	—	—	—	—	—	—	o-y	—	..
100.† } B. aureus lactis II.,	+	—	—	—	—	—	+	+	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	+	—	—	—	—	—	—	o-y	—	..
137,† - - -	+	—	—	+	—	—	+	—	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	+	±	—	±	—	—	—	o-y	—	..
78,† - - -	—	+	—	—	—	—	+	—	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	+	+	+	—	—	—	—	o-w	—	..

* Liquefaction. † No liquefaction.

GROUP IV.

Chromogenic type. Lemon yellow.

No. 48. B. lactis erythrogenes I.,	+	—	—	—	—	—	+	—	+	—	—	—	—	—	±	—	+	+	—	—	—	..	+	+	—	—	+	+	—	—	y	pk	—
116. B. lactis erythrogenes II.,	—	+	—	—	—	—	+	—	+	—	—	—	—	—	+	—	..	..	—	+	+	..	+	+	—	—	+	+	—	+	y	pk	—
174, - - -	+	—	—	—	—	—	+	—	+	—	—	—	—	—	+	—	..	..	—	+	+	..	+	—	+	—	±	—	+	—	y	pk	..
117. M. citreus lactis,	—	+	—	—	—	—	+	—	+	—	—	—	—	—	+	—	+	+	—	+	+	..	—	—	—	—	+	—	—	—	y	—	..
167, - - -	—	+	—	—	—	—	+	—	+	—	—	+	—	—	+	+	+	..	—	+	+	..	+	+	—	—	—	—	—	—	w-y	—	..
91. B. citreus acidi,	+	—	—	+	—	—	+	+	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	+	+	+	—	—	—	+	y	—	+
72, - - -	+	—	—	+	+	+	+	—	+	+	—	—	—	—	—	—	+	+	—	+	+	..	+	+	+	+	—	—	—	+	y	—	..
105, - - -	+	—	—	—	—	—	+	—	+	—	—	+	—	—	—	..	+	+	—	+	—	..	+	—	—	—	—	—	—	—	y	±	..
149. B. citreus lactis I.,	+	—	—	—	—	—	+	—	+	—	—	+	—	—	—	..	+	+	—	+	—	..	—	—	—	—	—	—	—	—	y	—	..
161. B. citreus lactis II.,	+	—	—	—	—	—	+	—	+	—	—	+	—	—	+	..	+	+	—	+	—	..	—	—	+	—	—	+	—	—	y	—	..
187, - - -	+	—	—	—	—	—	+	—	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	..	—	—	—	—	—	—	y	—	..
141, - - -	+	—	—	—	—	—	+	—	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	+	—	—	—	—	—	—	y	—	..
162, - - -	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	..	+	+	—	—	—	..	+	+	—	—	—	—	—	—	y	—	..
191. B. citreus arborescens,	+	—	—	—	—	—	—	—	+	—	—	+	—	+	—	..	±	+	—	+	—	..	..	..	—	—	+	±	—	—	y	—	..

TABLE I.—(*Continued.*)

Name and Number.	Morphology: Bacillus.	Coccus.	Diam. greater than 1μ.	Motile.	Uniting in chains.	Spores.	Cultural Features: Nutrient broth tube: Turbidity.	Scum.	Sediment.	Nutr'nt agar tube: Dull.	Wrinkled.	Gelatin plate: Characteristic.	Proteus-like.	Moss-like.	Gelatin stab: Liquefies.	Deep funnel.	Needle growth.	Surface g'wth.	Gas produced.	Potato tube: Visible.	Luxuriant.	Fermentation tube. Growth in closed arms.	Biochemical Features: Grows at body temperature.	Faculative anaerobic.	Milk: Curdles.	Acid.	Alkaline.	Digests.	Slimy.	Strong odor.	Chromogenesis.	Fluoresence.	Gas production.
GROUP V. **Micrococci, non-liquefying.**																																	
Division A.																																	
No. 78. M. acidi lactici I.,	—	+	—	—	—	—	+	—	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	+	+	+	—	—	—	—	w-o	—	..
60. M. acidi lactici II.,	—	+	—	—	—	—	+	—	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	—	+	+	—	—	—	—	—	—	..
58. M. acidi lactici III.,	—	+	—	—	—	—	+	+	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	—	+	+	—	—	—	—	—	—	..
168,	—	+	—	—	—	—	+	—	—	—	—	—	—	—	+	—	+	+	—	+	—	..	+	—	—	+	—	—	—	—	—	—	..
130. M. viscosus lactis,	—	+	—	—	—	—	+	—	—	—	—	—	—	—	—	..	+	+	—	+	—	..	..	+	—	+	—	—	+	—	—	—	—
Division B.																																	
70,	—	+	—	—	+	—	—	+	+	+	—	—	—	—	—	..	—	+	—	+	+	..	—	+	—	—	±	—	+	—	y.	—	..
75,	—	+	—	—	+	—	+	—	+	+	—	—	—	—	—	..	±	+	—	+	—	..	+	±	—	—	+	—	—	—	—	—	..
186,	—	+	—	—	+	—	+	—	—	—	—	—	—	—	—	..	—	+	—	+	—	..	+	..	—	—	—	—	—	—	—	—	..
80,	—	+	+	—	+	—	+	+	+	+	—	—	—	—	—	..	±	—	—	+	+	..	+	—	—	—	+	—	+	—	—	—	..
118. M. giganteus lactis,	—	+	+	—	—	—	—	—	—	+	—	+	—	—	—	..	+	—	—	—	—	..	+	+	—	—	—	—	—	—	—	—	..
47,	—	+	—	—	—	—	+	—	+	—	—	—	—	—	—	..	+	+	—	+	—	..	+	..	—	—	+	—	—	—	—	—	—
121. M. arborescens lactis,	—	+	—	—	—	—	+	+	+	—	—	+	—	+	—	..	+	+	—	+	+	..	+	+	—	—	+	—	—	—	—	—	..
85,	—	+	—	—	—	—	—	—	+	—	—	—	—	—	—	..	+	+	—	+	+	..	—	—	—	—	+	—	—	—	—	—	..

GROUP VI.

Micrococci. Liquefying, non-chromogenic.

No. 167. M. citreus lactis,	—	+	±	—	—	—	+	—	+	—	—	+	—	—	+	+	+	..	—	+	—	..	+	+	—	—	—	—	—	—	w-y	—	..
37,	—	+	—	—	—	—	+	—	+	—	—	—	—	—	+	—	..	..	—	+	+	..	+	+	+	—	±	—	—	—	—	—	..
109,	—	+	±	—	—	—	+	—	+	—	—	+	—	—	+	—	..	..	—	+	+	..	+	+	+	—	+	+	—	—	—	—	..
119. Sarcina alba,	—	+	—	—	—	—	—	—	—	—	—	—	—	—	+	±	..	..	—	+	+	..	+	+	+	—	±	—	±	—	—	—	..
142. M. communis lactis,	—	+	—	—	+	—	+	—	—	—	—	—	—	—	+	+	..	..	—	+	—	..	+	+	+	—	+	—	—	—	—	—	..
147. M. liquefaciens acidi I.,	—	+	+	—	—	—	—	—	—	+	—	+	—	—	+	—	..	..	—	+	+	..	+	+	+	+	—	—	—	—	—	—	..
168. M. liquefaciens acidi II.,	—	+	—	—	—	—	+	—	—	—	—	—	—	—	+	—	..	..	—	+	—	..	+	+	—	+	—	—	—	—	—	—	..
2. M. acidi lactis,	—	+	±	—	—	—	+	+	+	—	+	+	—	—	+	—	..	..	—	+	+	..	+	—	+	+	—	—	—	+	—	—	..

GROUP VII.

Bacilli and Bacteria. Non-liquefying and non-chromogenic.

Division A.

No. 125. B. coli communis,	+	—	—	+	—	—	+	+	—	—	—	—	—	—	—	..	+	+	+	+	+	..	+	+	+	+	—	—	—	—	—	—	+
89. B. coli communis,	+	—	—	+	—	—	+	—	—	—	—	—	—	—	—	..	+	+	—	+	+	..	+	+	+	+	—	—	—	—	—	—	+
208. B. lactis aerogenes,	+	—	—	—	—	—	+	—	+	—	—	—	—	—	—	..	+	+	—	+	+	+	+	+	±	+	—	—	—	—	—	—	+
107,	+	—	—	+	—	—	+	—	+	—	—	—	—	—	—	..	+	+	—	+	—	..	+	+	—	+	—	—	—	—	—	—	—
137,	+	—	—	+	—	—	+	—	—	—	—	—	—	—	—	..	+	+	—	+	+	..	+	+	±	—	±	—	—	—	—	—	—
93,	+	—	—	..	—	+	+	—	+	—	—	+	—	—	—	..	+	+	—	+	+	..	+	+	—	+	—	—	—	—	—	—	—
94. B. ubiquitus lactis,	+	—	—	—	—	+	+	—	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	+	+	+	—	—	—	—	—	—	—
206. B. acidi lactici I.,	+	—	—	—	—	—	+	—	+	—	—	+	—	—	—	..	+	—	—	—	—	+	+	+	+	+	—	—	—	—	—	—	—
202. B. acidi lactici II.,	+	—	—	—	—	—	—	—	—	—	—	+	—	—	—	..	+	—	—	—	—	—	+	+	+	+	—	—	—	—	—	—	—
41,	+	—	—	—	+	—	+	+	+	—	—	+	—	—	—	..	+	+	—	+	+	..	+	+	—	+	—	±	—	+	—	—	—

Division B.

126,	+	—	—	+	—	—	+	—	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	—	—	—	—	—	—	—	—	±	—
66,	+	—	—	+	—	—	+	—	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	—	—	—	—	±	—	—	—	±	—
84. B. communis lactis II.,	+	—	—	+	—	—	+	+	+	+	—	+	—	—	—	..	+	+	—	+	+	..	+	+	—	—	—	—	—	—	—	—	—
198. B. communis lactis II.,	+	—	—	+	+	—	+	—	+	+	—	—	—	—	—	..	+	+	—	+	+	..	..	+	—	—	—	—	—	—	y	—	—
194. B. communis lactis I.,	+	—	—	—	—	—	+	+	+	—	—	—	—	—	—	..	+	+	—	+	+	..	+	+	—	—	—	—	—	—	y	—	—
191. B. radiata lactis,	+	—	—	..	—	—	—	—	+	+	—	+	—	+	—	..	+	+	—	+	—	..	..	..	—	—	+	—	—	—	—	—	—
74. Proteus Zenkeri,	+	—	±	+	+	—	—	—	+	—	—	+	+	+	—	..	+	+	—	+	—	..	+	—	—	—	+	—	—	—	+	—	—
98,	+	—	—	+	+	—	+	—	—	—	—	—	—	—	—	..	+	+	—	+	—	..	..	—	—	—	+	—	—	—	—	—	—
12. B. viscosus lactis II.,	+	—	—	—	—	..	..	..	..	—	—	—	—	—	—	..	+	+	—	+	+	—	—	—	—	—	+	—	+	+	+	—	—
25,	+	—	—	+	—	+	+	+	+	—	—	—	—	—	—	..	+	+	—	+	—	..	+	+	—	—	+	—	—	—	—	—	—

TABLE I.—(*Continued.*)

Name and Number.	Morphology. Bacillus.	Morphology. Coccus.	Morphology. Diam. greater than 1μ.	Morphology. Motile.	Morphology. Uniting in chains.	Morphology. Spores.	Cultural Features. Nutrient broth tube. Turbidity.	Cultural Features. Nutrient broth tube. Scum.	Cultural Features. Nutrient broth tube. Sediment.	Cultural Features. Nutr'nt agar tube. Dull.	Cultural Features. Nutr'nt agar tube. Wrinkled.	Cultural Features. Gelatin plate. Characteristic.	Cultural Features. Gelatin plate. Proteus-like.	Cultural Features. Gelatin plate. Moss-like.	Cultural Features. Gelatin stab. Liquefies.	Cultural Features. Gelatin stab. Deep funnel.	Cultural Features. Gelatin stab. Needle growth	Cultural Features. Gelatin stab. Surface g'wth.	Cultural Features. Gelatin stab. Gas produced.	Cultural Features. Potato tube. Visible.	Cultural Features. Potato tube. Luxuriant.	Cultural Features. Fermentation tube. Growth in closed arms.	Biochemical Features. Grows at body temperature.	Biochemical Features. Faculative anaerobic.	Biochemical Features. Milk. Curdles.	Biochemical Features. Milk. Acid.	Biochemical Features. Milk. Alkaline.	Biochemical Features. Milk. Digests.	Biochemical Features. Milk. Slimy.	Biochemical Features. Milk. Strong odor.	Biochemical Features. Chromogenesis.	Biochemical Features. Fluoresence.	Biochemical Features. Gas production.
GROUP VIII. Liquefying Bacilli. No spores, non-chromogenic.																																	
No. 200. B. musci lactis,	+	—	±	—	+	—	—	+	+	+	—	+	+	+	+	+	+	+	—	+	—	..	+	+	+	—	+	—	—	—	—	—	—
196. B. varians lactis I., II., III.,	+	—	—	—	+	—	+	+	+	—	—	—	—	—	±	—	+	..	—	+	—	..	—	—	+	+	—	—	—	—	—	—	—
64. B. circulans II.,	+	—	—	+	+	—	—	+	+	—	—	+	—	—	+	+	—	..	—	+	—	..	+	—	+	—	±	+	—	+	—	—	—
164,	+	—	—	+	—	—	+	+	+	—	—	+	—	—	+	—	..	..	—	+	—	..	—	—	—	—	+	+	—	—	o	—	—
129,	+	—	—	—	—	—	+	—	—	—	—	—	—	—	+	—	..	..	—	+	+	..	..	—	+	—	+	+	+	—	—	—	—
120. B. anana,	+	—	—	+	—	—	+	+	+	—	—	—	—	—	+	+	..	..	—	+	+	..	+	..	+	—	+	—	—	+	—	—	—
68,	+	—	—	+	+	—	—	+	+	—	—	—	—	—	+	+	..	..	—	+	+	..	+	—	+	—	+	+	—	—	—	—	—
69,	+	—	—	+	+	—	+	+	+	—	—	—	—	—	+	+	..	..	—	+	+	..	—	—	+	—	+	+	—	—	—	—	—
GROUP IX. Liquefying Bacilli. Spores small.																																	
No. 207. B. subtilis,	+	—	±	+	+	+	—	+	+	+	+	+	—	—	+	—	..	—	—	+	+	+	+	+	+	—	+	+	—	—	—	—	—
177. B. megatherium,	+	—	+	+	+	+	..	..	+	—	—	—	—	—	+	—	..	+	—	+	+	..	—	+	..	..	..	..	..	—	—	—	—
184. B. lactis V. (Flügge),	+	—	±	—	+	+	—	+	—	+	—	+	—	+	+	—	+	+	—	+	+	..	+	..	—	—	+	+	—	+	—	—	—
145,	+	—	±	+	+	+	—	—	+	—	—	—	—	—	+	—	..	+	—	+	+	..	—	±	—	—	±	—	—	—	—	—	—
114. B. mesentericus fuscus,	+	—	—	+	+	+	+	—	—	+	+	+	—	—	+	—	+	—	—	+	+	..	+	+	+	—	+	+	—	—	—	—	—

GROUP X.

Liquefying Bacilli, with large spores.

	Division A.																																	
No. 123.*	B. arborescens lactis,	+	—	+	—	+	+	+	+	+	+	+	+	—	+	+	—	..	+	—	+	+	..	+	..	+	—	+	+	—	—	—	—	—
154.*	B. arborescens lactis,	+	—	+	—	+	+	+	+	+	+	+	+	—	+	+	—	..	+	—	+	+	..	+	+	+	—	+	+	—	—	—	—	—
131.*	B. filiformis lactis,	+	—	+	—	+	+	+	+	—	+	—	+	—	+	+	+	+	+	+	+	+	..	..	—	+	—	±	+	—	—	—	—	+
88,*	- - - - -	+	—	+	—	+	+	+	+	+	—	—	+	—	—	+	+	..	..	—	+	+	..	+	+	+	—	+	+	—	—	—	—	—
102.†	B. mycoides lactis I.,	+	—	±	+	+	+	+	+	+	+	+	+	+	+	+	+	..	..	—	+	+	..	+	+	+	—	+	+	—	+	—	—	—
124.†	B. mycoides lactis II.,	+	—	±	+	+	+	+	+	+	+	+	+	—	—	+	—	+	..	—	+	+	..	+	+	+	—	+	+	—	—	—	—	—
111.†	B. mycoides lactis III.,	+	—	+	+	+	+	+	+	+	+	+	+	—	—	+	—	+	..	—	+	+	..	+	+	+	—	+	+	—	—	—	—	—
138,†	- - - - -	+	—	±	+	+	+	—	+	+	—	—	—	—	—	+	..	..	..	—	+	+	..	..	+	+	—	+	+	—	—	—	—	—
150,†	- - - - -	+	—	—	+	+	+	+	+	+	—	—	+	—	—	+	—	..	..	—	+	+	..	+	—	+	—	+	+	—	—	—	—	—
51,	- - - - -	+	—	—	—	+	+	—	+	+	+	—	+	+	—	+	—	..	..	—	+	+	..	+	+	+	—	+	+	—	—	—	—	—
153,	- - - - -	+	—	+	+	+	+	—	+	—	—	—	+	—	—	+	+	..	..	—	+	+	..	+	+	+	—	+	+	—	—	—	—	—
	Division B. *Large spores at the end of the rod.*																																	
189.	B. arborescens lactis II.,	+	—	—	+	—	+	+	+	+	+	—	+	—	+	+	—	+	..	—	+	—	..	+	+	—	—	—	—	—	—	—	—	—
	Division C. *Two spores (?) in each rod.*																																	
190.	B. dispora lactis,	+	—	+	+	+	+	—	+	+	+	—	+	—	—	+	—	..	..	—	+	—	..	+	..	+	—	+	+	—	—	—	—	—

* Motile. † Non-motile.

DETAILED DESCRIPTION OF BACTERIA.

GROUP I. FLUORESCENT BACTERIA.

Bacteria which produce a blue-green color either in agar or gelatin or bouillon or in all three.

No. 21. (Very common.) *B. fluorescens Schuylkilliensis. (?)* (Wright.)

Morphology; .8μ by 2μ. Chains.

Gelatin plate; a large liquefying colony, greenish and granular, later becoming surrounded by a clear pit. Later the granular center breaks up into a diffused mass.

Gelatin stab; a shallow pit, becoming deep and broad. Later a horizontal liquid layer is formed with a scum and a precipitate, and a clear, green liquid between. Growth is very slow.

Agar; a thin, white, not very opaque, moist growth. Agar green.

Potato; diffusely spreading, very thin, moist and brown.

Milk; sometimes curdles in 3 days at 20°, and at other times fails to curdle. Alkaline, and there is a slight digestion.

This bacterium appears to agree most closely with *B. fluorescens Schuylkilliensis* (Wright), the differences being only within the range of variation.

No. 31. (Very common.) *B. fluorescens liquefaciens.* (Flügge.)

Morphology; size, 1.5μ by .9μ, forming long chains.

Gelatin plate; small round colonies, with radiating marking under the surface. Surface colonies become surrounded by a clear, granular pit, the center gradually disseminating into the pit.

Gelatin stab; slowly liquefying in a rather deep funnel. The liquid is *intensely green.*

Agar; white, smooth, moist and glistening.

Potato; thick and brownish.

Bouillon; liquid becomes *very green.*

Milk; a soft, slimy curd is produced at 20°, which begins to digest at once into a yellowish green alkaline liquid.

This seems to be one of the varieties of *B. pyocyaneus* (Gessard), and closely related to *B. fluorescens liquefaciens.* It is a very slow liquefier.

The many cultures of No. 21 and No. 31 which have been isolated and studied show considerable variation, and possibly several varieties have been here included which might be properly separated. But since they seem to belong to two types, I have recognized only the two above described.

Both of these species have been found many times in milk from all the localities studied, and while these organisms cannot be regarded as distinctively characteristic of milk or cream, they are so commonly found that their presence is not unusual. Whether they indicate, as has been sometimes assumed, that the milk has been adulterated or contaminated with water is a question that I do not feel that I have data for determining.

No. 128.

No. 128 is only slightly different from No. 21 and No. 31. The chief differences are the following: Its *size is considerably smaller*, being only *.5μ by .7μ*,

whereas the other two have a diameter of .8μ and a length of 1.5μ. In gelatin stab culture No. 128 produces a very shallow pit, whereas No. 21 and No. 31 produce a deeper pit; and, moreover, the liquefied gelatin is not rendered green, or only slightly so, by No. 128. The effect of this organism upon the milk is also very slight. While the milk is curdled in two or three days, there is little or no digestion of the casein; whereas, as shown by the tables, the casein is readily digested by Nos. 21 and 31.

That Nos. 21 and 31 are varieties of the same species seems to me almost certain. No. 128 is probably a different variety of the same species, and possibly is *B. fluorescens minutissimus.* (Unna.)

No. 5. *B. viscosus.* (Frankland.)

Morphology; size, 1μ by 2μ, but variable. Showing bi-polar staining. No threads are produced, but a capsule is present. No true spores, but the double stain gives the appearance of spores.

Gelatin plate; a small white colony is produced, which sinks into a pit and rapidly liquefies the gelatin. The pit has a granular center and a clear rim, and grows into a uniformly granular colony with a radiating rim. Only a slight tinge of green.

Gelatin stab; a narrow funnel is produced, with a thick tenacious scum on the surface, with a tendency to crack and wrinkle. The liquid becomes green and later yellow and slimy.

Agar; upon agar there is produced a thin, rough, white, dry skin, which is marvelously sticky, almost like glue. The agar becomes slightly green.

Potato; abundant, brownish yellow growth.

Milk; the milk is curdled at the room temperature in two days into a soft, *slimy* mass, with no whey, the reaction being alkaline. This becomes rapidly digested into a lemon yellow liquid; after the casein is all dissolved, the whole liquid is yellow and slimy. The odor is sickish, and the mass is very slimy. At 35° there is no digestion. It is further to be noted that after cultivation of about four months in the laboratory, this organism ceased to have the power of coagulating milk, although it continued to digest the casein at room temperature. The production of the lemon color also ceased.

The most distinctive characters of this organism are its *bi-polar staining and its production of a slime.* Experiments were performed with this specie, showing that it produced a soluble enzyme. The organism was cultivated in milk for some time, and then filtered through porcelain. The filtrate, which contained no bacteria, was found to have the power of coagulating milk in an hour's time at room temperature. From such filtrate an enzyme was isolated, as described in a previous publication.*

This organism appears similar to *B. viscosus.* (Frankland.)

Nos. 82 and 90. *B. fluorescens non-liquefaciens.*

Nos. 82 and 90 are without much doubt the same organism, and are probably identical with *Bacillus fluorescens non-liquefaciens* of Flügge. Slight differences led me to recognize two varieties, which appear in the descriptions. The organisms are not very common.

* Cent. f. Bact. u. Par., XII., 1892.

Morphology; a bacillus .6μ by 1.2μ to 2μ. No. 82 forms chains, while they were not found in No. 90.

Gelatin plate; the colony of No. 82 is at first round and opaque, but white. When reaching the size 1 mm. it becomes surrounded by a green halo. Later it becomes rough, irregular in shape, but still surrounded by the green halo. The colony of No. 90 spreads over the surface in a bluish white, clear colony, which frequently shows a darker granular center. No green halo appears.

Agar; a very thin, hardly visible growth is produced, which spreads over the surface, and the agar is turned green.

Bouillon; there is formed a thin scum with a very slight cloudiness, and subsequently a sediment appears. After several weeks the liquid is quite cloudy and a sediment is noticeable, which is greenish in the case of No. 82, and brownish in the case of No. 90.

Milk; this organism produces no noticeable effect upon milk at any temperature.

Both of these cultures were inoculated into pasteurized cream, and after the cream was allowed to ripen 24 hours it was churned. The butter produced had a moderately good flavor, though not strong, and hardly different from butter made from pasteurized cream without inoculation.

These six varieties which, as indicated, probably belong to four species, include all of the fluorescent forms which have been found in the dairy products in this vicinity.

GROUP II. CHROMOGENIC TYPE. (RED.)

No. 209. *Bacillus prodigious.*

Bacillus prodigious has been found a few times in milk in this vicinity.

No. 62. *Micrococcus rubidus lactis.* (n. sp.)

This species has been found only once, but it appears to be different from any previously described bacterium. It is a *coccus* form, *non-motile*, and fails to render milk red or to curdle it. In other characters it resembles *B. prodigious.*

Morphology; a coccus about 1μ, enveloped in a non-staining capsule.

Gelatin plate; rapidly liquefying colonies, commonly with red pigment, although many colonies fail to produce the pigment.

Gelatin stab; a narrow funnel, soon widening and depositing red pigment. The whole gelatin liquefies and becomes red.

Agar and potato; a blood red, thick, luxuriant growth. Pigment not produced at 35°. Pigment most profuse at 23°.

Milk; no curdling, although the milk becomes thickened slightly, with red margin. No change in reaction. In old cultures a mass of casein is seen floating in a clear liquid.

No. 42. *Micrococcus rosaceus lactis.* (n. sp.)

This specimen was obtained originally from Uruguay, but there was later isolated from milk in Middletown a culture that agreed with it in all essential respects.

Morphology; a micrococcus, .8μ in diameter, grouped in fours.

Gelatin plate; colonies 1 mm. in diameter, of a light pink color. Under a low power they show a nucleus with a lighter zone. Upon the surface the edges are thin and the center raised.

Gelatin stab; there is a slight needle growth and a slight surface growth, which is pink.

Agar and potato; a moist, thick, not widely spreading, pink layer.

Bouillon; after a few days a pinkish sediment makes its appearance. The liquid is cloudy, with no scum.

Milk; no curdling takes place. Reaction becoming slightly alkaline, with no digestion. After two weeks a very slight pinkish tinge is noticed in the milk, which becomes quite decided in a month. Later a pink scum forms, and the milk becomes somewhat slimy.

The distinctive characteristic of this species is the *pink color* produced, which shows in the gelatin colony, in the gelatin stab growth, in the growth on agar and potato, and in the sediment in the bouillon.

No. 115. (Somewhat common.) *Bacillus ruber lactis.* (n. sp.)

Morphology; a rod $.9\mu$ by 2μ to 4μ in length, occasionally forming long bent chains.

Gelatin plate; a white opaque bead, .7 mm. in diameter, formed on the surface of the gelatin, coarsely granular and broken around the edge. Gelatin liquefies rapidly, with a central mass and an outer granular zone, which is broken and lobed at first. Later the outer zone becomes clear as it expands, and the inner mass is broken into fragments.

Gelatin stab; a shallow funnel formed, with a thin liquid layer of gelatin over the whole surface of the tube, which gradually deepens. A dense sediment appears in a clear liquefied gelatin, but no scum.

Agar; a thick, coarsely folded growth, which may be at first yellow, but later *pink.*

Potato; smooth, thick, glistening growth, with a decidedly *pink* or *salmon* tinge. A very striking characteristic.

Milk; curdled in 4 days at body temperature. The curd is soft and alkaline, and soon digests into a colorless liquid. At 20° the milk does not curdle, but digestion occurs. When used for ripening cream it produces a good flavored butter, with a pleasant aroma, though neither taste nor smell are those of typical butter.

No. 151. (Rare.)

Morphology; Bacillus $.6\mu$ by $.7\mu$ to 1.2μ, blunt ends.

Gelatin plate; surface colony round, semi-transparent, liquefying gelatin slowly, with an *orange pink color.*

Gelatin stab; slight needle growth, with slow liquefaction. A slightly cloudy liquid is produced, with a thin scum.

Agar; moist, salmon pink growth.

Potato; a moist, light orange growth, which later becomes deeper and shows various shades, from *orange* to a *brilliant red.*

Milk; no effect for 10 days, except a slight pink scum around edge and a pink tinge to milk. Then it curdles into a soft curd, which later digests into an orange colored liquid. Is alkaline.

The two following groups, III. and IV., are separated from each other by the color of a pigment which they produce, the one giving a *lemon* yellow and the other an *orange* yellow pigment. It has been found by experience that brownish colors, especially upon potato, have no significance, but that lemon and orange yellow colors are quite distinct from each other, and may be used to characterize different groups. Occasionally forms may be found in which it is a little difficult to determine to which of these two groups they belong. For convenience in classification some of these forms have been included under both groups, but as a rule the yellow and orange are sharply separated.

GROUP III. CHROMOGENIC TYPE. (ORANGE.)

No. 199. *Sarcina flava.*

This species has been occasionally found in milk.

No. 188. *M. aureus lactis.* (n. sp.)

Morphology; a coccus, size, .8μ, in pairs or in clumps.

Gelatin plate; a round, opaque colony, surrounded by a halo which is uniformly granular, somewhat indented and cracked. This increases to a large, uniformly granular liquid zone, which spreads in all directions. The liquefaction at first is chiefly below the surface.

Gelatin stab; a shallow pit is produced, which deepens into a horizontal layer with a yellow sediment and slightly cloudy liquid. Liquefaction becomes complete.

Agar and potato; an abundant, moist, glistening Naples yellow growth.

Milk; after three weeks becomes curdled and rendered alkaline. Later is partially digested into a transparent liquid, with considerable undigested sediment.

No. 103. (Quite common.) *B. aureus minutissimus.* (n. sp.)

Morphology; a bacillus, size, .4μ by 1.6μ. Three or four may be united together, and in bouillon, long tangled threads.

Gelatin plate; surface colony at first thin, irregular, branching and creeping. The deeper colonies are *burr like*, with a yellow center and radiating processes. After two days a liquefying pit is formed, with a yellow center and *irregular processes* extending into the gelatin. The whole is quite characteristic.

Gelatin stab; a deep, narrow funnel, with a brilliant yellow sediment and scum, and a somewhat cloudy liquid.

Agar; an orange yellow growth, spreading over the whole surface.

Potato; a dark orange growth of a very deep color and striking appearance.

Bouillon; a slight scum on a uniformly cloudy liquid, and a yellow sediment collects after some weeks.

Milk; at 20° becomes somewhat pasty and dark colored. Slightly slimy, and is alkaline in reaction. Butter made from cream ripened with this organism develops an aroma of decay which is unpleasant. No very decided flavor.

Nos. 113 and 104. *Micrococcus varians lactis.* (n. sp.)

This is one of the most common of our dairy species, being found very commonly in milk and cream. It is frequently found in plates made by collecting dust that falls from the body of the cow during milking. It is a very widely variable species.* Its power of producing pigment varies from a deep orange to a pure white. It commonly liquefies gelatin rapidly, but some cultures have been found with this power only slightly developed and some in which it is wholly absent. In the table I have included two of the extreme types, and the variations are mentioned below.

Morphology; a coccus form, slightly variably in size, but about 1μ in diameter. It never forms chains, and stains easily.

Motility; none.

Temperature; grows readily at ordinary temperature. Grows rapidly at a temperature of 38°, but with less color.

Mica plate; grows under the mica plate, but not much in the middle. Evidently an aerobe with slight anaerobic powers.

Gelatin plate; colonies at first forming a whitish or yellowish bead on the surface, which sinks into a slight pit with an irregular edge. The pit broadens, liquefying the gelatin rapidly, and the colony breaks up into irregular yellow masses. The pit is sometimes very deep, and contains the irregular floating masses of bacteria. The general character of the colony is very characteristic, and can be readily distinguished at a glance from other liquefying colonies. The non-liquefying variety, No. 104, simply forms a yellow colony, not characteristic.

Gelatin stab; a broad, shallow funnel is produced, with a broken yellow scum and a yellow flaky sediment. Sometimes there is liquefaction along the needle track, and sometimes not. The liquefaction is rapid, and in a few days the gelatin is completely liquefied. No. 104 forms a shallow, dry pit, with a dense yellow surface growth.

Agar; a very characteristic, dry, rough, yellow growth. The color is slightly orange, though not very deep. From this the color varies to a pure white.

Potato; a dry, granular, orange yellow growth, abundant and characteristic. Color varies to a white, and sometimes the growth is moist rather than dry.

Bouillon; in two days a slight cloudiness is produced. In six days the liquid is very cloudy, but with no sediment. In four weeks very cloudy, with a yellow sediment.

Milk; curdles at 36° in three days into a soft curd, with an amphoteric reaction. At 20° it curdles in the same way in ten days. The curd is not subsequently digested, or only very slightly. When used for ripening cream in butter making, it produced very little flavor or aroma.

No. 159. (Rare.)

Morphology; a bacillus, size, .7μ by .9μ.

Gelatin plate; characteristic. A mounded, yellowish, spreading colony, which becomes *1 centimeter in diameter, thin and almost invisible* on the edge. Is irregular shaped and very yellow.

* The variations of this species have been previously described in the Cent. f. Bact. u. Par., II., V., p. 665.

Gelatin stab; a good needle growth, with a thick yellow orange surface growth.

Agar and potato; thick, moist, glistening yellow, of a very deep orange shade.

Milk; no effect produced on milk.

Nos. 162 and 141.

See the same numbers under Group III. They are listed here also, since the pigment sometimes approaches an orange color rather than a lemon yellow.

No. 169. (Rare.)

Morphology; a bacillus, size, .5μ by 1μ. Has an irregular stain, with light spots in the middle that are not true spores. On potato they grow to a length of 4μ, with square ends, still showing irregular stain.

Gelatin plate; deep colonies are round and yellow, with a dark center and a yellow rim. Surface colonies are about .5 mm. in diameter. They are yellow and *transparent*, the transparent colony being the most distinctive character.

Gelatin stab; an abundant needle growth, with a thin, widely spreading, transparent surface.

Agar; an orange yellow, transparent, moist growth.

Potato; A widely spreading, moist, orange growth, sometimes very deep in color and almost brown.

Bouillon; orange flakes appear on the surface, and later a yellowish sediment.

Milk; is not curdled, but an orange scum and an orange sediment are produced, and the milk rendered alkaline.

No. 170. *B. aureus acidi.* (n. sp.)

Morphology; a bacillus, size, .6μ by .7μ. Occasionally somewhat longer.

Gelatin plate; colonies under the surface round, yellowish and slightly opaque. Surface colonies rather transparent, spreading, slightly irregular, 1.5 mm. in diameter, and of an orange color.

Gelatin stab; a deep, dry pit is produced, with a dry orange yellow skin lining the pit.

Agar and potato; both show an orange yellow growth.

Milk; is curdled in from two to four weeks into a moderately *hard curd, which is acid*, showing no whey and having no digestion.

No. 205. *B. aureus lactis I.* (n. sp.)

Morphology; a bacillus, size, .6μ by 1μ, with rounded ends. No chains, though three or four may adhere together.

Gelatin plate; under the surface a yellowish orange, slightly irregular colony. On the surface an orange bead, .5 mm. in diameter, which is in the middle of a slightly depressed ring, but no liquefaction of gelatin occurs.

Gelatin stab; a good needle growth and a slight orange surface growth appears.

Agar; a moist, thick, smooth ground glass growth, orange yellow in color.

Potato; a dry, or moist, orange growth.

Bouillon; an *orange yellow, tenacious scum* appears with a clear liquid.

Milk; no effect produced, except an *orange scum* and an alkaline reaction.

No. 100. *B. aureus lactis II.* (n. sp.)

Morphology; a bacillus, size, .5μ by .7μ. No chains, though two or three adhere together.

Gelatin plate; a bead with a smooth edge and a dark center is produced, 1.5 mm. in diameter, which, after a few days, becomes decidedly yellow.

Gelatin stab; a slight needle growth, with an irregular, opaque, white surface growth, not very thick.

Agar; smooth, whitish growth, which, after a few days, acquires a lemon color, and later a Naples yellow color.

Potato; an abundant growth, which is at first white, or slightly yellow and quite thick, later becoming decidedly yellow.

Bouillon; a thick, *tenacious scum* is produced, which sinks in the form of flakes, and produces a sediment.

Milk; no effect produced on milk, except that a slight slimy scum sometimes appears. Butter made from cream ripened with this organism has a prominent flavor, which is not normal and unpleasant. There is a slight and tolerably pleasant aroma. The butter on the whole is of a good quality. Nos. 205 and 100 are perhaps the same.

No. 137.

Morphology; a bacillus, size, .6μ by 1.2μ, or occasionally larger, with round ends.

Gelatin plate; the deep colonies are round and slightly granular. On the surface they spread into a thin, transparent colony, which later becomes thicker and brown and yellowish. It may occasionally form a thick, yellowish bead.

Gelatin stab; a moderate needle growth, with a yellowish irregular surface growth, with a slightly raised edge.

Agar; a not very abundant dull yellow growth.

Potato; spreads over the surface of a thin, decidedly yellow growth.

Milk; commonly curdled at room temperature in about two weeks, though sometimes becomes simply slightly lumpy. At body temperature it curdles completely, though the curd is rather soft. The action is amphoteric, and there is no digestion. No effect on butter.

No. 78. (See Group V.)

GROUP IV. CHROMOGENIC TYPE. (LEMON YELLOW.)

Nos. 48 and 116. *B. lactis erythrogenes.* Varieties I. and II.

These two cultures I regard as varieties of *B. lactis erythrogenes*, although one is a typical bacterium and the other a coccus. Variety I. appears to agree with *B. lactis erythrogenes* of Hueppe. They have each been found several times and differ from each other in a few constant characters. But since the few differences remained constant with cultivation, I have found it convenient to separate them as Varieties I. and II. Variety I. liquefies gelatin very slowly, or not at all, while Variety II. liquefies rapidly. Variety I., moreover, does not grow on potato, and turns milk red; while Variety II. grows on potato, forming an abundant yellow growth, but it does not turn milk red. The characters of Variety II. are as follows:

No. 116. *B. lactis erythrogenes.* Variety II.

Morphology; a large coccus, .8μ in diameter.

Gelatin plate; the colony is at first a bead, or flat and brownish under the microscope. Grows into a flat colony, 1.5 mm. in diameter, in four days, and then sinks into a shallow pit.

Gelatin stab; an abundant needle growth, white, with a flat, white surface growth sinking into a shallow pit, the bacteria mass forming a dense scum on the surface of the liquefying gelatin. Liquefaction occurs slowly and horizontally.

Agar; a thick, white, opaque growth, giving to the agar a *pinkish tinge*, which later becomes somewhat red. The growth on the surface becomes yellow.

Potato; an abundant yellow, moist, opaque skin.

Milk; is rendered slightly alkaline, but not curdled. After four weeks it is digested into a watery or semi transparent liquid, yellowish in color, with a peculiar smell. It produces no effect upon butter when used for cream ripening.

No. 174. (Uncommon.)

Morphology; a bacillus, size, .9μ by 1.5μ, with rounded ends. No chains, though three or four may hang together.

Gelatin plate; the deep colonies are oval, dark, opaque, and the surface colonies are at first white and about half a millimeter in diameter, thin, sinking into a pit, with a large, yellowish nucleus.

Gelatin stab; a moderately shallow funnel is produced, gradually liquefying, with a cloudy liquid and abundant sediment, but no scum.

Agar; slightly lemon yellow growth on the surface, and the agar acquires a *pink tinge.*

Potato; white or yellow growth, which later becomes quite abundant and lemon yellow.

Milk; curdles at body temperature in three days into a soft, alkaline curd. Digests into a cloudy, colorless mass, which sometimes may be reddish yellow or amber colored, and with a slimy scum.

This organism is very similar to No. 116, above described, and is perhaps identical with it. The pink fluorescence is very slight, and the lemon yellow color more noticeable, and this has led me to separate the two.

No. 201, *Sarcina lutea*, and No. 199, *Sarcina flava*, have both been found occasionally in dairy products.

No. 117. (Rare.) *Micrococcus citreus lactis.* (n. sp.)

Morphology; a coccus, .9μ in diameter.

Gelatin plate; a smooth, opaque surface colony, 1 mm. in diameter, which in about five days becomes 2.5 mm. in diameter; very *thin and flat and decidedly yellow.* Gelatin ordinarily becomes dry before liquefaction begins.

Gelatin stab; needle growth abundant. A flat, depressed, yellow surface growth, which is sunken in the middle and slowly spreads over the surface of the gelatin. After about two weeks a slow liquefaction begins, with a floating scum on the surface of the liquid. (One variety of this species was found which liquefied the gelatin more rapidly and produced a narrow funnel.)

Agar; abundant moist growth of a brilliant yellow.

Potato; a rather dry but abundant lemon yellow growth.

Milk; rendered strongly alkaline, but no further change produced. No noticeable effect produced upon butter when used in cream ripening.

No. 167. (See Group VI.)

I regard this as a variety of No. 117. It grows, however, at 35°, and under a mica plate, and liquefies more slowly.

No. 91. (Rare.) *B. citreus acidi.* (n. sp.)

Morphology; a bacillus, size, .5μ by .8μ, with no chains.

Gelatin plate; large, white, opaque colony, becoming 2 mm. in diameter, and later turning yellow.

Gelatin stab; a good needle growth, with a spreading surface, slightly raised on the edge and depressed in the centre. This becomes lemon yellow and spreads slowly over the surface.

Agar; an abundant, spreading, lemon yellow surface growth.

Potato; a thick, white and slightly transparent growth, the center of which soon becomes yellow, and later the whole turns to a lemon yellow.

Bouillon; a slight scum is formed, which sinks in the form of flakes and produces an abundant sediment.

Milk; curdled at ordinary temperatures in 6 to 9 days with a clear, hard curd and a deep yellow layer of milk on top. *Is acid* and has a decidedly *sour odor*, with no digestion. Cream is also curdled and filled with gas bubbles. It is acid, and has a pleasantly sour odor, with no separation of whey. Used for cream ripening, it produces a good butter flavor, though slight, but no aroma.

No. 72. (Rare.)

Morphology; a bacillus, size, .8μ by 1.4μ. Produces very short chains with spores. In old cultures long threads may be developed.

Gelatin plate; produces a perfectly transparent surface colony, with an irregular edge, half a millimeter in diameter.

Gelatin stab; a moderate needle growth and a dry, white, moderately abundant surface growth.

Agar; opaque, white and shining at first and abundant. Later becomes a lemon yellow.

Potato; thick, smooth growth, which may be white where moist, but soon becomes lemon yellow.

Milk; curdles at 36° in two days, but not at room temperature. Is *acid.* No effect is produced on cream, except an acidity and sour smell and taste. Butter made from such cream has a sour, unpleasant taste. When fully ripened, has an unpleasant aroma, and is decidedly poor.

No. 105. (Rare.)

Morphology; a short rod, size, .5μ by .9μ.

Gelatin plate; colonies under the surface are rounded or oval, with a dark center and a lighter outer zone, which is sometimes lobed or striated. On the surface large, moderately opaque beads are formed.

Gelatin stab; slight needle growth, but a moderately thick, white surface growth, which later becomes dry, with a slight yellow tinge.

Agar; the agar develops on the surface a very decidedly lemon yellow growth, which is thick and abundant. The agar may, at the same time, be turned *green*, but not universally so.

Potato; growth thin and moist, but lemon yellow.

Bouillon; slightly cloudy, and with a slight tinge of *green* near the surface.

Milk; no effect upon milk at any temperature. Butter made from cream ripened with this species has no special flavor or aroma.

No. 149. (Common.) *B. citreus lactis I.* (n. sp.)

Morphology; a rod, size, 1μ by .7μ, with rounded ends. On potato and agar the rods are connected with a slimy capsule.

Gelatin plate; a minute colony, 1 mm., or a little larger. On the surface there is frequently produced a raised bead, with a central dot. The color is lemon yellow, brilliant, and even under the microscope the colonies appear *brilliant lemon yellow*, smooth and clear.

Gelatin stab; needle growth moderate to the bottom of the tube. A rough surface growth, rather thick, but not opaque.

Agar; a thin, moist, transparent lemon yellow growth.

Potato; a moderately thick, brilliant lemon yellow growth.

Milk; no effect is produced on milk or upon cream.

While quite similar to No. 105, this species differs in its gelatin colony and its *intense lemon yellow pigment.* It is quite common in milk.

No. 161. *B. citreus lactis II.* (n. sp.)

This organism agrees with the last described in all respects, except two. First, it liquefies gelatin slowly, producing a dense yellow liquid in the gelatin stab. Second, associated with this characteristic it is found that it curdles milk, producing a weak alkaline curd at ordinary room temperature.

These two organisms are apparently the same species, differing in the power of liquefying gelatin, and consequently curdling milk.

Both No. 149 and No. 161 have been found quite commonly in the milk in this vicinity, and in one case both of these types have been isolated from a single colony.

No. 187. (Rare.)

Morphology; a rod, size, .8μ by 1μ to 1.2μ. No chains, spores nor capsules.

Gelatin plate; a round, semi-opaque, slightly yellow colony produced, with no characteristic features.

Gelatin stab; a moderate needle growth, with a slightly raised surface growth. Faint yellow, but not characteristic.

Agar; a moist, smooth, glistening, lemon yellow growth.

Potato; an abundant, moist, glistening, lemon yellow growth.

Milk; no effect upon milk or cream.

This organism has no characteristic features, except the *lemon yellow color* which is produced on gelatin, agar and potato. I separate it from No. 149 because of the very moderate pigment it produces.

No. 141. (Rather common.)

Morphology; a bacillus, size, .6μ by 1μ to 2μ.

Gelatin plate; the deeper colonies are round, brown and opaque. Surface colony is more transparent, whitish and finely and uniformly granular.

Gelatin stab; a moderate needle growth, with a dry, white, spreading surface growth. Moderately thick. Somewhat irregular edges.

Agar; a thick, moist growth, which is at first white, with a tinge of yellow, later becoming lemon yellow.

Potato; coarse or fine folded skin, with a yellow color.

Milk; no effect produced on milk or cream.

No. 162.

This agrees with No. 141 in all respects, except that the growth on potato is very scanty, and there is scarcely any growth in bouillon. The two probably are the same.

No. 191. (Rare.) *B. citreus arborescens.* (n. sp.)

Morphology; a rod, size, .8μ by 4μ. Two or three may adhere together, but no long chains. Is joined by a capsule that does not stain.

Gelatin plate; a widely spreading colony, with *fine radiating rods* growing from the center, and some growing over the whole plate, with fiber permeating the gelatin in every direction. *These fibers have frequent knobs.* The fibers from two colonies will extend over a whole plate in three days. To the naked eye they look like a mould. This growth is very characteristic.

Gelatin stab; needle growth is slight, but a thick *ground glass surface* growth is produced.

Agar; white, moist and irregular, spreading in streaks over the surface.

Potato; dry and thin, but lemon yellow in color.

Milk; no effect, except a slight transparency and an alkaline reaction.

GROUP V. NON-LIQUEFYING COCCI, NOT CHROMOGENIC.

Division A.

Organisms which curdle milk with an acid reaction.

No. 60. (Very common.) *M. acidi lactici I.* (Marpmann.)

Morphology; a coccus, .6μ in diameter, growing in masses.

Gelatin plate; forms rounded beads, finely granular, but with a smooth edge, and not characteristic.

Gelatin stab; moderate needle growth, rough and beaded. The surface is rough and irregular, moderately thick.

Agar; an opaque, white growth, which may grow down into the agar from the needle track, later becoming Naples yellow.

Potato; white, somewhat thick and spreading, and later becoming yellow.

Milk; at 20° is *rendered acid*, but not curdled, though such milk will curdle when boiled. At 35° is curdled into a hard curd which is *acid*. Cream is slightly thickened, rendered acid and sour. Butter made from the same has a decidedly good flavor, but practically no aroma.

No. 78. *M. acidi lactici II.*

This organism agrees with No. 60, except that it occasionally produces yellow pigment, and does not so readily grow without oxygen. The two are probably the same, and they are very similar to the following.

No. 58. *M. acidi lactici III.*

Morphology; diameter, .8μ.

Gelatin plate; a colony, at first yellowish, then raised into a white bead. Not characteristic.

Gelatin stab and agar; not characteristic.

Potato; an extremely abundant, thick, shining growth. It may sometimes be 2 mm. to 3 mm. in thickness, of a flesh color, and is especially characteristic.

Milk; is rendered strongly acid, but does not curdle at 20°, though it curdles at 35°. Cream acquires a rather strong, sharp, penetrating, pleasant odor.

These three organisms appear to me to be similar to *B. acidi lactici* of Marpmann.

No. 168. (Rare.)

Morphology; coccus, .9μ, and diplococci.

Gelatin plate; the deep colonies are round and opaque. On the surface they grow into a snow white bead, extremely opaque, which grows to the size of 2 mm., and then sinks into a pit, which sometimes liquefies and sometimes does not.

Gelatin stab; a beaded needle growth. On the surface there is formed a white skin, which sinks into *a pit, commonly dry*, though sometimes with a slight liquid.

Agar; an abundant snow white growth.

Potato; a hardly visible thin white streak.

Milk; is rendered acid and curdles when heated, but does not curdle normally.

This organism may be identical with No. 147 (Group VI.). As seen from the above description, it is probably a liquefier whose power of liquefaction is sometimes completely lost. In other respects it agrees very closely with No. 147.

No. 130. (Rare.) *M. viscosus lactis.* (n. sp.)

Morphology; a coccus, .9μ in diameter.

Gelatin plate; surface colonies are smooth and shining white; colonies ½ mm. in diameter, and not opaque.

Gelatin stab; slight needle growth. An abundant shining white surface growth, raised into a mound.

Agar and potato; not characteristic.

Milk; becomes acid, but does not curdle. It soon becomes *extraordinarily slimy*, and can be drawn out into long threads. The sliminess does not affect the churning of the cream, and produces no flavor or aroma in the butter.

This coccus does not appear to be like any of the previously described slimy milk bacteria, and I have therefore regarded it as new, and given it the name, *M. viscosus lactis.*

Division B.

Organisms which do not curdle milk nor render it acid.

The first three agree in producing chains (*Streptococci*), and differ only slightly from each other. They may perhaps be the same.

No. 70. (Common.)

Morphology; .6μ in diameter, forming chains in bouillon.

Gelatin plate; a surface colony, 1 mm. in diameter, rather opaque, with an irregular border, or sometimes a thick, raised bead.

Gelatin stab and agar; not characteristic.

Potato; cream white or yellowish white. Abundant and somewhat transparent, moist and *slimy*. Used for ripening cream, it produces a good flavored butter, without any sour taste.

No. 75. (Common.)

Morphology; diameter, .6μ; in bouillon growing into chains, with a capsule.

Gelatin plate; smooth, thick and transparent, 2 mm. in diameter, with occasional tendency toward roughness, and warts on the surface.

Gelatin stab; a slight needle growth, tapering rapidly below the surface. The surface is rather thick on the edge, with a smooth center. Is dry and transparent.

Agar; is yellowish white, quite thin and *dry*, and not widely spreading.

Potato; a dirty white or *snow white growth*. Used for cream ripening, it produces butter without taste or flavor.

No. 186. (Common.)

Morphology; diameter, .8μ to .9μ, occasionally forming short chains of 6 to 20 elements, especially in bouillon.

Gelatin plate; a round, opaque, slight yellow colony, spreading into a white, slightly raised colony, finely granular, .5 mm. in diameter.

Gelatin stab; a typical *nail colony*, with a round, smooth head, quite thick, at first white, but later showing a tinge of yellow.

Agar and potato; not characteristic.

No. 80. (Rare.)

Morphology; diameter, *1μ to 1.2μ*. Slightly longer than broad. Forms chains of 6 or 8, which resemble rods, but which break up into cocci in old colonies.

Gelatin plate; a slightly granular, white rather transparent colony, 1 mm. in diameter. Not characteristic.

Gelatin stab; needle growth slight; thin, smooth, semi-transparent surface growth.

Agar and potato; not characteristic.

Milk; is rendered somewhat *slimy* and alkaline, but otherwise unchanged. Produces butter without flavor or aroma.

No. 118. (Rare.) *M. giganteus lactis.* (n. sp.)

Morphology; extremely large coccus, 1.5μ in diameter.

Gelatin plate; produces an opaque, white bead. Not characteristic.

Gelatin stab; an abundant needle growth, but no surface growth.

Agar and potato; no visible growth, and the same is true of bouillon.

Milk; produces no effect upon milk.

The essential characteristics of this organism are its *very great size* and its markedly *anaerobic characters.* One type, probably the same, produces a very slight *acid* reaction in the milk after four weeks growth, sufficient to curdle the milk when heated.

No. 47. (Uncommon.)

Morphology; .6μ in diameter.

Gelatin plate; a round, raised, white bead, 1 mm. in diameter.

Gelatin stab; an abundant needle growth, with a thick, moist but not widely spreading surface.

Potato and agar; snow white, moist growth.

No. 121. (Somewhat common.) *M. arborescens lactis.* (n. sp.)

Morphology; diameter, .7μ. No chains.

Gelatin plate; deep colonies are irregular, granular, with a broken *fuzzy edge.* On the surface they are more regular, and become 1 mm. in diameter. There is great variation in density and in the amount of irregularity.

Gelatin stab; needle growth with *radiating fibers.* The surface growth is white, not thick, and spreads over the surface.

Agar and potato; not characteristic.

Bouillon; a very tough, *tenacious scum* is formed, which does not sink in the liquid.

No. 85. (Somewhat common.)

Morphology; .6μ in diameter.

Gelatin plate; a transparent bead, with a darker center and a scolloped border, 1 mm. in diameter. This bead is rather transparent, and spreads slightly.

Gelatin stab and agar; not characteristic.

Potato; thick and whitish, or *yellowish,* or sometimes *creamy white.* In cream the organism produces a pleasant odor, but butter made from it has no flavor or aroma.

GROUP VI. MICROCOCCI. LIQUEFYING, BUT NON-CHROMOGENIC.

No. 167. (Somewhat common.) *M. citreus lactis.* (n. sp.)

Morphology; a coccus, 1μ in diameter, in groups of 4, or irregular masses.

Gelatin plate; produces an opaque bead in a slight depression, which increases to 1 mm. in diameter, then sinks in a pit, in which the bead remains for some time in the center as a raised mound. The pit may be granular and either circular or lobed.

Gelatin stab; needle growth abundant, with not much surface at first. Later a deep, dry, narrow pit is formed, with a dense, white growth covering its walls. Still later the gelatin liquefies, and a yellowish sediment is produced.

Agar; opaque, abundant growth, with a tinge of yellow.

Potato; rather dry, whitish or with a yellowish tinge.

Bouillon; becomes uniformly cloudy, with no scum and with a *slimy* sediment. Another culture of what I regard as the same species produces a liquid pit instead of a dry pit, as here described.

Milk; culture does not curdle milk. This is the only one of the liquefying cocci found that fails to curdle milk.

I regard this as identical with No. 117 of Group IV.

No. 37. (Rare.)

Morphology; a *minute cocci*, .3μ to .4μ in diameter.

Gelatin plate; a small, granular colony, surrounded by a clear, liquefying ring. Later the nucleus breaks up, diffusing through the liquid, sometimes regular, sometimes irregular.

Gelatin stab; growth is slow. A narrow pit is formed, with an air bubble at the surface. Liquefaction complete in six weeks. Liquid is cloudy, with a heavy sediment.

Agar and potato; dirty white growth. Not characteristic.

Milk; is curdled, with weak alkaline reaction, in two days, at room temperature. At 36° in three days. A digestion follows, which is never complete.

Chiefly characterized by its *minute size.* Found only once.

No. 109. (Rare.)

Morphology; a coccus, 1μ in diameter.

Gelatin plate; a round, smooth surface colony, moderately transparent. Grows to the size of 1.5 mm., usually very flat, with a central mound, and then sinks into a pit, upon which it forms at first a very dense surface scum.

Gelatin stab; slight needle growth; a very shallow, dry pit is produced at first, in which liquid begins to collect after four or five days. Liquefaction produced very slowly in a horizontal layer.

Agar and potato; not characteristic.

Milk; is curdled at body heat in seven days, quite solid, and strongly alkaline. At room temperature it digests without curdling. The liquid is at first watery, soon becoming amber color, and later the color deepens, sometimes even to a *mahogany* color. When used for cream ripening no effect is produced on the butter.

No. 119. (Rare.) *Sarcina alba (?)*

Morphology; a sarcina form, .6μ to .8μ in diameter.

Gelatin plate; a slightly yellow, round, raised, opaque colony, which soon sinks into a pit. The pit remains clear, with a rough, granular nucleus.

Gelatin stab; a very narrow liquefying pit is produced, with a cloudy liquid. This broadens below the surface. Sometimes, however, a shallow, deep, dry pit is formed.

Agar and potato; a whitish, not abundant and not characteristic growth.

Milk; curdles in three days at 20° and in one day at 36°. Reaction amphoteric. Digestion of the curd very slight, or none. When used for ripening cream it produces a good flavored butter, with a good and typical butter aroma. One culture that I have regarded as the same produces a digestion of milk into a very *slimy jelly*.

No. 142. (Common.) *M. communis lactis.* (n. sp.)

Morphology; a *streptococcus*, with the elements .8μ to 1μ in diameter.

Gelatin plate; a round, brownish colony, slightly irregular in shape. Edge becomes after a couple of days somewhat lighter and surrounded by a liquefying pit, in which the granules spread irregularly. Occasionally a few blunt processes *radiate from the center.* The pit is rather large and at first is dry, subsequently liquefying.

Gelatin stab; a narrow funnel, with a dense, cloudy liquid is produced, with a deep, dry pit at the top. Below the air bubble the funnel spreads out into a turnip shape.

Agar; an almost *snow white* growth.

Potato; thin and watery, and spreading over the whole surface.

Milk; is curdled at 36° in three days, with amphoteric reaction. At room temperature curdles in three weeks. The curd is soft, with no whey, and the subsequent digestion is slight.

No. 147. (Common.) *M. liquefaciens acidi I.* (n. sp.)

Morphology; diameter, .7μ to 1.1μ, grouped in fours by dividing in two directions.

Gelatin plate; a densely granular liquid colony is produced, with a granular center, which is lobate or with folded edges, and which lies in a clear, liquefying pit. Later dense masses are formed outside of the center, and the whole pit becomes filled with irregular masses.

Gelatin stab; slow liquefier, producing a cloudy, shallow pit, with dense sediment. A scum with broken fragments appears. Even after three weeks gelatin is liquefied only for a quarter of an inch.

Agar and potato; a dry, snow white growth, quite opaque.

Milk; at 36° curdles in five days into a hard curd, with little whey. *Is acid in reaction, and has the smell of sour milk.* At room temperature the action is the same, although the acid is not quite so prominent. No digestion subsequently occurs, but a large amount of whey separates from the curd.

No. 168. *M. liquefaciens acidi II.* (n. sp.)

This agrees with No. 147 in many points, and may be the same. The following differences were noted:

Gelatin plate; a snow white bead, very opaque, is formed, growing to size of 2 mm., when it sinks into a slowly liquefying pit. Some colonies do not liquefy before the growth ceases.

Gelatin stab; a granular needle growth and a dense white surface on a slowly liquefying mass of gelatin.

Potato; growth is hardly visible.

Bouillon; becomes very cloudy.

Milk; is rendered acid, but the amount of acid is *insufficient to curdle* the milk unless it is heated.

These two cultures appear to me to be new, and their characteristics are so marked that I have ventured to give them a name.

No. 2. *M. acidi lactis.* (Krüger.)

Morphology; 1μ to 1.2μ in diameter.

Gelatin plate; at first a slight pit, which begins to liquefy, the colony being uniformly granular. The granules soon break up, distributing themselves through the pit, usually producing a nucleus, with a peripheral ring of granules. Outside the ring there may be a clear liquid outer zone. Eventually the whole becomes densely granular.

Agar; growth on the surface tends to become wrinkled, tenacious and sticky, and develops a yellowish or slight *salmon* color.

Potato; an abundant growth, somewhat *folded*, of a *flesh* or *salmon* color.

Milk is curdled at 20° or at 36° into a hard coagulum, with orange masses floating on the top. The reaction is *acid.* No digestion occurs. After a few days yellow lumps of fat frequently appear on the surface. Chemical analysis has shown butyric acid and alcohol to be present.

The last three organisms are peculiar in *liquefying gelatin*, but curdling milk with an *acid reaction.* This is unusual. Three or four such micrococci have been described before by Hueppe, Freudenreich, Krüger and Kozai. I have concluded that No. 2 may be the same as the species described by Krüger and Kozai.

GROUP VII. NON-LIQUEFYING, NON-CHROMOGENIC BACILLI.

This group, which is the most important group of dairy bacteria, is a very difficult one to arrange in any satisfactory manner. The different species are frequently very similar to each other, and the diagnostic characters difficult to determine. I am convinced that in some cases quite different bacilli are put under the same species because of difficulty in getting diagnostic characters for separating them.

I have found it most convenient to separate them, first in accordance with their power of producing an acid reaction in milk, and secondly in accordance with their morphological characters. A few are readily distinguished by their peculiar gelatin colonies, and some by their spore production.

Division A.

Bacilli producing an acid reaction in milk.

Nos. 125 and 89. *B. coli communis.*

This species of bacillus is extremely common in milk, although by no means universally found. It seems to show considerable variation. The two numbers above given are two of the many distinct cultures which I have identified with *B. coli.* They differ slightly. No. 125 shows gas bubbles in the gelatin

stab, while No. 89 does not, and No. 125 curdles milk more slowly, not curdling for two weeks, while No. 89 curdles in six days.

Both have been used for ripening cream, but produce butter with a markedly sour taste.

While this species is very common, it is rarely abundant enough to produce much influence upon the milk. It can therefore hardly be regarded as a distinctive dairy bacterium.

No. 208. (Extremely common.) *B. lactis aerogenes. (?)*

Probably identical with *B. acidi lactici* (Grotenfeld) and *B. a.* and *b. of* Guilleleau, and *No. 8* of Eckels.

This is one of the most common species found in milk and cream. It is not only almost always found, but is also usually very abundant. Sometimes it appears to be the cause of the spontaneous souring of milk, since in some samples it is the only acid bacillus found. This is unusual, however, for though very common, it is usually far outnumbered by No. 206 and No. 202. It is also very variable in its physiological characters, as explained on page 24, but the many different cultures which I have studied have in general the following characters.

Morphology; size, .7μ by 1μ, with rounded ends.

Gelatin plate; deep colonies, opaque and oval. (Litmus gelatin turned very red.) Sometimes lobate, as if made up of many colonies. Surface colonies may be large (2 mm.), white, opaque beads, which may contain a gas bubble (dextrose gelatin). Sometimes they form projecting colonies, growing up from the surface of the gelatin to the height of 1.5 mm., though not more than .5 mm. in diameter. Sometimes they are like *B. coli* colonies, only more luxuriant.

Gelatin stab; abundant needle growth and a thick, white surface growth.

Agar; white, moist, glistening and semi-transparent. Abundant.

Potato; a creamy white, abundant, not folded growth. Moist.

Milk; at 20° rendered strongly acid, but commonly not curdling. Some cultures do curdle. At 35° curdles milk two to four days into a soft curd. In all cases the milk is strongly *acid.* There is a *typical sour milk odor.*

Fermentation tube; grows strongly in closed arm and in bulb, and produces much gas.

This includes Nos. 16, 53, 56, described in previous publications (Storrs Expt. Sta. Rep., 1890 and 1894).

The next two organisms belong to the *Typhosus type* (Fuller) which ferment milk sugar, but produce no gas.

No. 107. (Rare.)

Morphology; size, .6μ to .8μ by 1.3μ.

Gelatin plate; a thin, transparent, spreading colony, elevated into irregular ridges, becoming a centimeter in diameter, or larger.

Gelatin stab; an abundant needle growth, with a thin, transparent, spreading, irregular surface growth. *Hardly visible.*

Agar and potato; not characteristic.

Milk; not curdled at either 20° or 36°, but rendered acid, and will curdle when heated. Butter made from cream has a sour, clean taste, but not much flavor. A strong, but not typical aroma.

No. 137. (Rare.)

Morphology; size, .6μ by 1.2μ, variable.

Gelatin plate; spreading into a thin, transparent surface colony, which later becomes thicker and brownish or yellowish. It may even form a thick, yellowish bead, half a millimeter in diameter.

Gelatin stab; a good needle growth, white. On the surface an irregular, yellowish growth, spreading slightly and rather thick on the edge.

Agar; a dull yellow, transparent, but not abundant growth.

Potato; a thin, yellowish layer, which upon some moderately dry potatoes may be quite thick, but still yellowish.

Milk; sometimes not affected in the room, but in other cases is curdled in about two weeks into a soft, lumpy, incomplete curd. At 36° the *curdling* is more complete, but still soft, and the reaction is *amphoteric.* It has no effect upon butter.

This is the only non-liquefying organism found which curdles milk without rendering it acid.

The next two organisms differ from the others in producing spores.

No. 93. (Rare.)

Morphology; size, 1μ by .6μ, or in old cultures slightly larger. The old cultures show large oval spores, larger than the rods.

Gelatin plate; an irregular surface colony, streaked over the surface with irregular contorted lines. Grows to the size of 2 mm. on the surface. Colonies under the surface are lobed.

Gelatin stab; a good needle growth, with a thick, white, surface growth.

Agar; very thick and opaque and white. Later becoming somewhat yellowish.

Potato; very thick and transparent; of a whitish color, which later becomes dry and folded.

Milk; does not curdle at 20°, though will when heated. At 36° curdles in three days. Cream is rendered acid and sour, and butter made therefrom has rather an unpleasant, sour, cheesy taste.

No. 94. *B. ubiquitus lactis. (?)*

Morphology; size, .8μ by 1.2μ to 1.4μ. In bouillon short chains are produced. A bipolar staining is shown, and spores are eventually produced in the middle of the rods. A non-staining capsule developed.

Gelatin plate; round, white, opaque colonies, with a dark center, frequently raised to form a bead.

Gelatin stab; abundant needle growth. Surface raised, white, forming a prominent nail head. The center is more elevated than the edge.

Agar; extremely irregular, spreading, thick, very white and smooth.

Potato; grows with extreme rapidity, forming a *transparent, white, glistening,* widely spreading growth, especially characteristic.

Milk; curdles in eleven to twelve days. Cream rendered acid and sour, and butter produced therefrom has especially good flavor, with no aroma.

I have with hesitation associated this with *B. ubiquitus* (Jordan). The differences between the two are considerable. Jordan does not describe any spore formation, and he states that *B. ubiquitus* curdles milk very rapidly, while No. 94 curdles it only after several days.

No. 206. *B. acidi lacti I.* (Esten.)

This organism, described in a previous Report of this Station (1896), must be regarded as the most important milk bacterium in the dairies of this vicinity. As described in that paper, it has been found almost universally in samples of milk from a very wide range of territory. It is by no means universally present, and if the milk from different cows be carefully studied separately, it is found that in many cases samples of milk are obtained with no specimens of this particular species present. But when mixed milk is studied it is found in almost all cases to contain this organism. Moreover, in the milk of ordinary dairies this organism forms the largest proportion of the bacteria present. In my studies of the bacteria of ripened cream it has been found that a proportion varying from 75% to 90% of the bacteria present in cream are of the species here described. It must, therefore, be looked upon as *the* dairy organism par excellence. Its description, though given elsewhere, may be for completeness sake best included here, and is as follows:

Morphology; short, plump rods, size, .7μ by 1.2μ. No chains are produced, and no spores are found.

Gelatin plate; in ordinary gelatin a small, finely granular colony produced, pearly white by reflected light, though slightly yellowish by transmitted light. In milk sugar gelatin rendered blue by litmus, the shape of the colony is characteristic and easily recognized. It is a round, opaque colony, the surface of which is always provided with *minute spines.* This spiny appearance is distinctly characteristic of this organism.

Gelatin stab; grows wholly below the surface as a rough, beaded needle track, with no surface.

Agar; no growth or a very thin, *almost invisible layer.*

Potato; growth on potato is scarcely visible.

Bouillon; becomes turbid and a sediment collects, but there is no scum, and no gas is produced.

Milk; is curdled in from six to twenty-four hours into a homogeneous jelly like curd, very hard, and containing no gas bubbles. There is no further change in the milk. It is intensely acid, and has a clear taste, with no odor.

This species is apparently identical with those described by Günther and Thierfelder, Leichmann, Weigmann and Kozai.

No. 202. *B. acidi lactici II.* (n. sp.)

Morphology; a short bacillus or coccus, .7μ by .8μ.

Gelatin plate; an extremely small, clear, slightly yellowish colony is formed, never more than 1 mm. in diameter. It grows wholly under the surface or under a mica plate, but never on the surface.

Gelatin stab; grows along the needle track as a beaded, tolerably abundant growth, but no surface growth.

Agar and potato; there is no growth whatsoever upon these, nor is there any perceptible growth in bouillon. In a *fermentation tube* containing milk sugar bouillon there is no growth even in the closed arm.

Milk; is curdled in thirty-six hours to four days into a hard homogeneous curd, which is strongly acid. There is no separation of whey and no subsequent change.

This organism, next to the last, is the most common of our dairy species. It is found with practical universality in samples of mixed milk, and is present in very great numbers in ripened cream. While the number of this organism in ripened cream is not as great as in the case of the last species, the proportion is always high, and frequently reaches 20% in samples of typical ripened cream. This organism and the last comprise in many cases over 95% of the bacteria in the normally ripened cream, and they must therefore be regarded as the two most important dairy organisms in this region. *Neither of them produces the typical sour milk odor*, such as is developed by No. 208.

No. 197. *B. lactici aerobans.* (n. sp.)

This agrees with No. 202, except that it has no effect on milk, and its growth on agar is visible though very scanty.

Possibly these are the same as *Bacillus a.* of Freudenreich.

No. 41. (Originally found in milk from Uruguay.)

Morphology; a bacillus, occasionally clinging two together, and on potato frequently forming chains. Size, 1.1μ by $.6\mu$. When growing in potato it is slightly longer than in agar. No spores.

Temperature; grows best at about 20°–23° C.; at 35° scarcely any growth; killed by temperature of 60° C. in ten minutes.

Gelatin plate; a smooth, round colony under surface. On surface a small, grey, raised bead-like colony, spreading somewhat, reaching size of 1 mm. occasionally. Not characteristic. After several years cultivation the gelatin colony was found to be always burr shaped, with irregular, more or less radiating margins.

Gelatin stab; slight needle growth. Spreads over surface as a moist, white, thick mound, forming a nail growth. Does not liquefy.

Agar; an abundant, white, smooth, glistening layer,

Potato; raised, thick, whitish or slightly yellow-tinged layer, differing in color with amount of moisture, When very moist, is white, but when dry tends to a yellowish tinge. Grows profusely. A pleasant *aromatic odor* developed.

Milk; does not curdle either at 20° or 35°. After two to three weeks becomes slightly translucent and brownish. The reaction is slightly acid. After three to four weeks it seems to digest into a translucent mass. It acquires a *pleasant aroma.*

This bacterium has been used widely for cream ripening, producing a pure flavored butter.

Division B.

Bacilli not rendering milk acid.

No. 126. (Rare.)

Morphology; a bacillus, size, .7μ by 1.2μ.

Gelatin plate; an opaque bead, 1 mm. in diameter, slightly scolloped edge. Very white, opaque.

Gelatin stab; typical nail growth. Not characteristic.

Agar; thick, white and abundant. The agar occasionally tinged green or yellow.

Potato; a yellowish or dirty white growth. Not characteristic.

Milk; no effect. Butter made from cream ripened with this organism has a *cheesy aroma and taste.*

No. 66. (Common.)

Agrees with No. 126, except that the milk is rendered slightly alkaline and the cheesy taste does not appear in the butter. Butter on the other hand develops an excellent nutty flavor of the highest quality.

Possibly these two organisms should be classified with the fluorescent, inasmuch as they occasionally render the agar slightly green.

No. 84. (Common.)

Morphology; size, .6μ by .8μ to 1.2μ. Occasionally six or eight unite together, but no long chains.

Gelatin plate; a rounded bead, with a smooth edge, finely granular and with a dark center. It spreads over the surface as a dry, thin growth, 2 mm. in diameter.

Gelatin stab; needle growth abundant. Surface growth dry, irregular and glistening.

Agar; widely diffused growth, branching irregularly and lobate. Yellow color.

Potato; growth thin and of a yellowish or brownish or even orange color.

Milk; no effect upon milk, cream or butter.

No. 198. (Common.) *B. communis lactis II.*

Morphology; size, .8μ by 1μ. Forms short chains in bouillon.

Gelatin plate; colony of the B. coli type. Surface colony spreads into a white, bluish growth, 1.5 mm. in diameter. They are slightly yellow under the microscope, and may have a somewhat raised center. The colony is moist and glistening.

Gelatin stab; abundant needle growth, with a thin, slightly spreading, white, dry, surface growth.

Agar; not characteristic.

Potato; a slight lemon yellow tinge, but not characteristic. No effect upon milk or cream.

Differs from No. 84 chiefly in the form of the *gelatin colony.* Probably the same as No. 26. Previously described. (Storrs Sta. Rep., 1893.)

194. (Very common.) *B. communis lactis I.* (n. sp.)

Morphology; size, .6μ by .8μ.

Gelatin plate; a smooth, round, white colony, not very opaque, becoming 3 mm. in diameter, irregular and rough or lobate, or sometimes round, white, moist and regular.

Gelatin stab; needle growth abundant. A white, flat, glistening surface growth, which is first thin, but later becomes thicker and slightly yellow.

Agar; moderately thick, moist, smooth and transparent.

Potato; white, moist and thick.

Milk; no effect upon milk or cream.

This is very common in milk, though never in great numbers. It is the same as No. 55. Previously described. (Storrs Sta. Rep., 1893.)

No. 191. *B. radiata lactis.* (n. sp.) (Named also *B. citreus arborescens* on p. 43.)

Morphology; size, .8μ by 4μ. No long chains, but two or three may be united together. Surrounded by an unstained capsule.

Gelatin plate; widely spreading colony, with fine lines radiating from the center. Grows over the whole plate, with fibers permeating the gelatin. The fibers are knobbed. Fibers from two colonies may grow over the whole plate in the course of three days. To the naked eye the whole looks like a mould.

Gelatin stab; a slight needle growth, with a characteristic ground glass surface growth.

Agar; not characteristic.

Potato; a very thin growth, which may be slightly lemon yellow.

Milk; after three weeks is rendered slightly alkaline and semi-transparent.

This organism was found only once, and was unfortunately lost before its description was complete. Its very unique colony upon gelatin is, however, sufficient to distinguish it.

No. 74. (Rare.) *Proteus Zenkeri.* *(?)*

Morphology; size, 1μ by 2μ to 3μ, forming long threads in bouillon.

Gelatin plate; colonies especially characteristic. They start as round colonies, from which extend fine branches. These radiate widely and are at first fine and subsequently polypiform. Sometimes they are simply fine, radiating lines, not polypiform, and occasionally the colony is simply lobate, without radiating fibers.

Gelatin stab; along the needle track are lateral extensions forming *thin sheets*, thus producing the form of an inverted fir tree. Surface growth thin and irregular.

Agar; spreads rapidly from the needle track, with radiating fibers rather thick.

Potato; dirty white, brown, rough, with a sandy appearance.

Milk; no effect except a slight alkalinity. After three weeks it becomes slightly slimy. No effect on cream or butter made from the cream. Develops no aroma or taste.

No. 98. (Rare.)

Morphology; size, .7μ by 1.5μ to 2μ. Joining into chains.

Gelatin plate; a round, rough, granular colony, sometimes coarsely granular like a corn ball.

Gelatin stab; a moderate needle growth, with a thin, transparent, widely spreading, *hardly visible* surface.

Agar; moderately thick along the needle track, but with a thin, transparent, *hardly visible*, spreading edge growing over the agar.

Potato; rather scanty, but not characteristic.

Milk; no effect upon milk or cream. Butter develops a rather unusual aroma, but no flavor.

No. 12. (Rare.) *B. viscosus lactis II.* (n. sp.)

Morphology; a rod, four times as long as broad (size not measured), surrounded by a mass of slime.

Gelatin plate; a white bead, 1 mm. in diameter. Not characteristic.

Gelatin stab; abundant needle growth, with a thin, irregular rosette surface growth.

Agar; transparent and glassy, very thick and raised in irregular masses. The growth is extremely slimy, forming threads several inches long when lifted with the platinum loop.

Potato; growth greyish brown, mottled, abundant, tenacious, and slimy.

Milk; is rendered slimy and alkaline. Threads of a foot in length may be drawn from it with a platinum loop. An odor is developed in the milk, reminding one of *strong cheese.* After a month the milk becomes almost solid, although its sliminess has disappeared.

This bacillus appears to be similar in its general characters to *B. viscosus lactis* of Adamitz, but its morphology is quite different. While *B. viscosus* is nearly as broad as long, this No. 12 is a long, slender rod. It was isolated from milk in 1891, and has not been found since.

No. 25.

Morphology; a bacillus, .7μ by 2μ.

Gelatin plate; a minute, clear, round colony is produced, which is later raised into a bead, with concentric folds. It may spread to a diameter of 1 mm., and show a central nucleus with a dark outer rim. The edge may be rough and folded.

Gelatin stab; an abundant needle growth, which is rough and beaded. A slightly mounded surface growth, spreads widely and later is thin, transparent and dry. Color is white.

Agar; is white, moist and moderately thick.

Potato; is white or gray, dry and thick. Later it becomes yellowish and even brown.

The most convenient grouping of the liquefying bacilli has been found to be that adopted by Flügge, depending upon the character of the spore formation. It should be stated,

however, that less attention has been given to the liquefying bacteria than to the non-liquefying bacteria. While they are almost always present in milk, their relative number is always small in normal milk. The rapid growth of the numerous lactic bacteria commonly checks the multiplication of the liquefyers, so that they are always few in ordinary milk or cream. I am now convinced that they are of comparatively little importance in normal dairy processes. In ripened cream, as will be shown in a later paper, they are commonly only to be found in very small quantities. For these reasons less attention has been given to them in my investigations, and the list given below is therefore doubtless far from complete. The bacteria here listed doubtless include some of those described by Duclaux under the name of *Tyrothrix*, but the incompleteness of his description makes sure identification impossible. I have therefore not attempted to identify them with Duclaux's species.

GROUP VIII. LIQUEFYING BACILLI WITHOUT SPORES.

No. 200. (Rare.) *B. musci lactis.* (n. sp.)

Morphology; size, 1μ by 2μ to 5μ. Forms long chains, which look like strings of sausages. These form a tangled mass, forming a scum on gelatin.

Gelatin plate; a diffuse colony, 1 inch in diameter, made up of long fibers, growing chiefly under the surface of the gelatin, looking like a tuft of moss, thick in the center and gradually fading out around the edge. Quite characteristic *network of fibers.*

Gelatin stab; a ground glass, crumpled surface. Below surface there is a tree-like growth from the needle track, hardly visible. Liquefaction takes place slowly. There is eventually produced a liquid cone, with a central granular axis, shaped like an inverted cone. Eventually the liquefaction is complete.

Agar; widely spreading, with creeping branches on the surface like cotton threads. Eventually covering the whole surface.

Potato; growth is chiefly *under the surface.* The surface becomes rough and white and somewhat broken.

Bouillon; masses are formed floating in a clear liquid, and a scum appears later.

Milk; is curdled after three weeks, and becomes slowly digested into a translucent mass, full of flakes and showing a skin on the surface of a ground glass appearance.

No. 196. (Common) *B. varians lactis I.* (n. sp.)

Morphology; size, .8μ by 1.5μ, blunt ends.

Gelatin plate; a thin, spreading, transparent surface. When reaching a millimeter in diameter it sinks into a pit in a dense, granular mass. Sometimes

a few lobe-like shoots extend from the colony into the gelatin, *ending in prominent knobs*, quite characteristic.

Gelatin stab; a shallow cone produced. The gelatin then liquefying regularly into a dense, cloudy liquid.

Agar and potato; scanty growth, but not characteristic.

Milk; is curdled hard and rendered amphoteric, or sometimes acid. No digestion can be seen, but a watery whey subsequently deposits from a solid curd.

Nos. 176 and 139. *B. varians lactis II. and III.*

These two cultures I place with No 196. They agree in all points except the power of liquefying gelatin. No. 139 in gelatin stab forms a deep, dry pit, with no sign of liquid. No. 176 produces a dry pit, but later begins to liquefy at the bottom, and the liquefaction slowly deepens, while No 196, as shown, liquefies rapidly. The three were obtained from different localities and at different times.

They may be identical with *B. cloacae* (Jordan).

No. 64. (Rather common.) *B. circulans II.* (n. sp.)

Morphology; size, .6μ by 1.5μ. Long chains are produced in bouillon, but no spores found.

Gelatin plate; a granular bead is produced, which sinks into a dry pit. The pit liquefies, and the bacilli can be seen actively *circulating in the liquid.* Uniformly granular.

Gelatin stab; there is a growth along the needle track, producing a deep, narrow funnel, from which the liquid evaporates, so that there is a considerable portion of the funnel without liquid. A white sediment forms in the axis of the liquefying pit. The whole is peculiar and characteristic.

Agar; an abundant, yellowish growth. Not characteristic.

Potato; a somewhat thin, watery, transparent growth.

Milk; there is no curdling, but the milk digests into a weak alkaline liquid, which is cloudy and gives off unpleasant odors. Butter made from cream ripened with this organism develops a moderately good flavor and aroma. The putrefactive odor in the milk and cream is ordinarily not noticeable in the butter.

This is very similar to *B. circulans* of Jordan. I have, however, found no spores, while Jordan found them in most media. The growth on agar is also different. The peculiarities shown in the colony and the gelatin stab lead me to put it with the species described by Jordan as a *Variety II.*

No. 164. (Rare.)

Morphology; size, .5μ by .8μ to 1μ. Tapering ends and showing irregular stain.

Gelatin plate; a yellow colony in a deep pit. As liquefaction begins there is a curiously figured central lobate mass, with an outer clear zone.

Gelatin stab; a shallow, dry pit appears, which soon shows liquefaction at the bottom, an air bubble remaining for some time. Later liquefying over the whole surface into a cloudy liquid, with a dense sediment.

Agar; semi-transparent, thick growth.

Potato; moist, not very abundant growth, which may show an orange or brownish pigment.

Milk; is slowly digested without curdling into a red amber colored, watery liquid, with a jelly-like mass of undigested casein at the bottom. Is alkaline.

No. 129. (Rare.)

Morphology; size, .8μ by 1μ to 3μ.

Gelatin plate; colony at first irregular or round. It soon becomes rough and margined, and branches arise. It then develops into a liquefying colony, with a nucleus and radiating markings.

Gelatin stab; a slow liquefaction. There is a shallow pit, becoming a horizontal layer, of a cloudy liquid.

Agar; moist, white and thick. It spreads irregularly over the agar.

Potato; at first smooth, white and moist, but later becoming slightly yellowish and folded.

Milk; is curdled with an alkaline reaction and then slightly digested, the liquid becoming slimy.

No. 120. (Rare.) *Bacillus anana.* (n. sp.)

Morphology; size, .5μ by 1μ to 1.2μ.

Gelatin plate; a round, opaque, granular colony, breaking up to form a pit, covered with mottled, granular masses. There is frequently a nucleus and a zone of granular fragments.

Gelatin stab; a narrow pit, with a granular liquid. The pit broadens at the surface and contains very cloudy liquid. Later the whole gelatin is liquefied.

Agar; moist, white, abundant.

Potato; very thick, white and abundant, and having the *odor of pineapple.*

Milk; curdles at 20° into a soft curd. No digestion noticeable. No curdling at 36°.

No. 68. (Rare.)

Morphology; size, .6μ by 1μ. Shows uneven stain and a capsule.

Gelatin plate; a pit forms, filled with irregular masses. It is frequently rosette formed at first, but breaks into opaque granules as the liquefaction begins.

Gelatin stab; a deep, dry pit formed, which later liquefies, a scum appearing on the liquid.

Agar; white, moist, thick at center of the inoculation line, but with a thin, scolloped edge. Later it becomes yellow.

Potato; a very profuse, *abundant, moist, jelly-like* growth covering the whole potato. May be white or yellowish. Very characteristic.

Milk; may curdle, or digest without curdling. Is alkaline. In about twelve days it becomes a nearly transparent liquid with a yellow scum. No effect on butter when used for ripening cream.

This is similar to No. 120, except for its action on milk.

No. 69. (Rare.)

Morphology; size, .8μ by 2μ.

Gelatin plate; a liquefying colony, with a nucleus and a broad, granular margin, or sometimes uniformly granular without the nucleus.

Gelatin stab; a narrow funnel, which widens as it liquefies into a broad funnel. The liquid has a granular tinge at the surface, and is cloudy, with a slight granular sediment.

Agar; rapid growth, spreading widely into a white, opaque layer, with irregular, glistening edge.

Potato; white, or cream white, and semi-transparent.

Milk; curdles in five to six days into a soft curd, which is alkaline. It then digests into a colorless liquid, with a bitter taste. Produces butter with a sharp, sour taste, but a thoroughly *typical butter aroma.*

GROUP IX. LIQUEFYING BACILLI WITH SPORES NO LARGER THAN THE ROD.

No. 207. *Bacillus subtilis.*

Not an uncommon inhabitant of milk.

No. 177. *Bacillus megatherium.*

This species has been found once or twice. It is easily recognized from its great size, 2.5μ, in diameter, and its spores of much less diameter. Its complete characters have not been studied here.

No. 184. (Rare.) *B. lactis V. (?)* (Flügge.)

Morphology; a large rod, with square ends forming long chains.

Gelatin plate; liquefies rapidly. Under the surface appear opaque, rough gelatin colonies, with a fibrous rim. Colonies liquefy rapidly, spreading into a uniformly granular or fibrous colony, 2 cm. in size in two days. When the colonies are near together the fibers become twisted and look like anthrax colonies.

Gelatin stab; needle growth abundant. There is a horizontal liquefaction, with a rough, white, wrinkled, tough *skin, looking like a mould.* The skin later becomes somewhat yellow, and the gelatin is finally completely liquefied, with a yellow scum.

Agar; abundant, rough, whitish yellow skin, with an irregular edge.

Potato; a very abundant growth, thick and dry, forming an almost *powdery white* surface.

Milk; no curd appears, but the milk digests in one to two weeks into a translucent liquid, with a thick, *folded scum* on the surface. It is strongly alkaline.

This appears to me to be quite similar to *B. lactis V.* (Flügge). It differs, so far as can be determined from his description, only in its action on milk, which, in Flügge's organism, did not produce the folded skin on the surface of the digested milk.

No. 145. (Rare.)

Morphology; size, 1μ by 3.5μ, blunt ends. Long chains occasionally produced. Spores spherical.

Gelatin plate; colony liquefies when it reaches the size of 1 mm., forming a dense, white layer, covering the whole surface of the liquefying pit.

Gelatin stab; liquefies at first as a small cone, and this slowly spreads over the whole surface, becoming covered with a dense, white film.

Agar; not characteristic.

Potato; very thick, dirty white layer, slightly transparent and gelatinous.

Milk; no effect upon milk either at 20° or 35°.

No. 114. (Rare.) *B. mesentericus fuscus.*

Morphology; size, .8μ by 2μ, forming long chains.

Gelatin plate; deep colonies are round, smooth and transparent. The surface colonies are raised, with a thin, transparent edge and irregular rim, creeping over the surface in irregular lobes. In five days it reaches the size of 1 mm., then it sinks into a liquefying pit, the colony remaining as a *dense growth over the whole surface*, with no clear liquid ring surrounding it.

Gelatin stab; needle growth abundant. A very shallow pit, with an air bubble in its center. The pit later spreads over the whole surface.

Agar; a somewhat dry, slightly folded growth.

Potato; a gray or yellowish, thick, highly folded skin.

Milk; at 20° does not curdle but digests slowly and becomes alkaline. At 26° curdles in six days and digests. Cream ripened with this organism produces butter with no aroma nor flavor.

GROUP X. BACILLI WHICH LIQUEFY GELATIN AND FORM SPORES LARGER THAN RODS.

These easily recognizable bacteria I divided into three divisions, according to the position of the spore.

Division A. Spores in the middle of the rod (spindle formed).
Division B. Spores at one end of the rod (tetanus type).
Division C. Two spores (?), one at each end of the rods.

Division A.

Spores in the center of the rods.

No. 123. (Rather common.) *B. arborescens lactis.* (n. sp.)

Morphology; size, 1.8μ by 3μ, growing into long chains. Large spores produced of a size 1.2μ by 2μ, causing the rods to swell in the middle.

Gelatin plate; colony grows into a large *felted ground glass mass*, which sinks slowly in a shallow pit.

Gelatin stab; a thick, ground glass surface growth forms as a scum floating on a shallow funnel. This eventually becomes much folded. Later the whole becomes liquefied, and the scum remains folded and tenacious.

Agar; grows into remarkably spreading branching filamentous masses which cover the whole surface and even grow under the surface. Quite characteristic.

Potato; almost snow white, abundant growth which extends into the potato. The surface is raised into folded mounds.

Milk; rapidly curdled at 20° and at 35°, and digested into a cloudy, colorless or amber colored liquid with alkaline reaction. Butter made from cream ripened with this organism has an unpleasant flavor and aroma.

No. 154.

This organism is probably a variety of No. 123, differing only in growth on potato and in bouillon. The potato growth is scanty, the surface becomes covered with a slight, fuzzy growth, and later with small, rounded knobs containing spores. There is an abundant growth below the surface. In bouillon a jelly-like, tenacious, flocculent mass is formed in the liquid. In other respects this agrees with No. 123.

No. 131. (Rare.) *B. filiformis lactis.* (n. sp.)

Morphology; size, 1μ by 2μ. The rods have a thick capsule with a central staining body. Spores are 1.2μ by 1.8μ in size.

Gelatin plate; colony has a fine, granular center, breaking at its edge into a granular margin surrounded with a clear, liquefying zone. Later the margin shows *contorted lacing threads.*

Gelatin stab; a narrow, cylindrical liquefying funnel is formed, with a cloudy liquid. Much gas is produced showing *as bubbles on the surface of the liquid* as well as the gelatin. Sometimes, after long cultivation, it grows without producing this gas. Liquefaction becomes complete and a dense scum and sediment is formed.

Agar; may be dry and thin, but commonly forms a thick, widely spreading lobate or branching mass, which is dry, white and quite characteristic.

Potato; a moist, yellowish, slimy mass grows over the surface.

Milk; curdled in two days with little change in reaction. Cream is rendered slightly acid with a sour cream taste, and butter made therefrom has a good flavor, but no aroma.

No. 88. (Rare.)

Morphology; size, 1.5μ by 3μ. Chains of a dozen elements are formed and large spores produced in bouillon.

Gelatin plate; a liquefying pit filled with filaments. A central granular nucleus forms with coarse granular masses, which become uniformly distributed in the surrounding zone.

Gelatin stab; a simple pit is formed which at first contains no liquid, but later liquefaction occurs slowly.

Agar; yellowish or white, not characteristic.

Potato; decidedly lemon yellow at first and later becoming dry, wrinkled and quite yellow.

Milk; curdles at 20° in six days with a thick scum and a little whey. Is alkaline in reaction. Digests into an especially clear liquid with a tenacious scum and sediment. Cream develops an unpleasant odor and the fat separates as masses floating in the whey. Butter made therefrom has no taste nor aroma.

The following three organisms show considerable similarities, especially in their morphology. But the type of colony they produce in gelatin is so different that I cannot regard them as identical. They resemble somewhat the

B. mycoides of Flügge, although each shows distinct points of difference from Flügge's organism. I have therefore named them *B. mycoides lactis I., II., III.*

No. 102. (Common.) *B. mycoides lactis I.* (n. sp.)

Morphology; 1μ by 2μ in length, forming long chains with oval spores.

Gelatin plate; deep colonies are at first irregular and show irregular radiating fibers. *A proteus-like colony.* The surface colonies form a pit with a large nucleus and a loosely granular outer zone. Liquefaction slowly extends.

Gelatin stab; a narrow funnel broadening at the top is formed, with a dense sediment. It liquefies then over the surface of the gelatin, and the liquefaction deepens uniformly with a very granular liquid containing a dense white sediment.

Agar; growth is tough and *dry* and *broken easily into fragments.* Later becomes *very white* from being covered with spores.

Potato; dry and rough and even, becoming *snow white.*

Milk; curdles in two days at 36° into a soft curd, faintly alkaline. Curdles also at 20°. Digests slowly producing a rancid odor. The digested liquid is colorless, though when the digestion is complete the liquid may be amber colored. It is without effect upon the flavor or aroma of butter.

No. 124. (Common.) *B. mycoides lactis II.* (n. sp.)

Morphology; size, 1μ by 2μ. Grows into long threads. The individual elements show square ends. A capsule is developed and large spores are prominent.

Gelatin plate; a pit is formed in which a tangled mass of threads is formed very much *like anthrax colonies.* It is quite characteristic. Becomes half a millimeter in diameter and then liquefies.

Gelatin stab; a shallow funnel is produced which liquefies in a horizontal layer. The liquid is clear with a dense scum and a dense sediment.

Agar; a tough, white growth is formed, readily breaking into lumps.

Potato; growth thin and dry, almost snow white, commonly a *putty-like* texture.

Milk; curdles rapidly at 36° in one day and at 20° in a week. Digests into a cloudy liquid which is colorless or amber colored.

No. 111. *B. mycoides lactis III.* (n. sp.)

Agrees with No. 124 except in the following points:

Gelatin stab; peculiar radiating growth arises from the needle track. This is unlike the common "fir tree" type, inasmuch as the radiating growths are in branches and are as long at the top as at the bottom of the gelatin. They grow moreover obliquely rather than horizontally. Later the liquefaction begins and is finally complete.

Potato; this grows into a dry, *velvety,* spreading growth all over the surface. Later becomes very snow white and dry.

No. 138. (Rare).

Morphology; size, 1μ by 2μ to 3μ, Forming long threads in bouillon. Rods with square ends.

Gelatin plate; brownish granular colonies with an irregular edge, which become surrounded by a liquefying pit. The pit is finely granular with a nucleus. A nucleus soon breaks up into variously formed irregular masses and the whole colony becomes uniformly granular.

Agar; not characteristic.

Potato; much folded into thick, *contorted folds*, with a yellowish tinge.

Milk; the milk is, after several days, curdled into a soft curd, which digests at once into a colorless liquid, completely dissolving the casein. Cream ripened by this organism develops a very unpleasant flavor and aroma in the butter.

No. 150. (Uncommon.)

Morphology; size, .7μ by 1.3μ. Long threads of rods with rounded ends.

Gelatin plate; colonies 2 mm. in diameter forming thick, raised, yellowish masses lying in a broad pit. Liquefaction proceeds slowly; the colony remains as a flat, dense, opaque mass, folded and wrinkled. Later a peculiar *snow white mass arises in the center of the colony* looking like a mould. This is extremely peculiar and very characteristic.

Gelatin stab; a shallow pit is produced. The growth is slow, and a clear liquid is formed with a dense, yellow scum, but no sediment. Later the liquid becomes cloudy and a sediment collects which may be white or yellow.

Agar; not characteristic.

Potato; develops a wrinkled, brown skin, which later becomes dry and highly folded.

Milk; is curdled in four days at 36° and in two weeks at 20°, into a soft alkaline curd. It eventually digests into a somewhat transparent mass, but the digestion is incomplete. A very pleasant odor is developed.

No. 51. (Rare.)

Morphology; size, .8μ by 1.5μ to 2μ. Rods with square ends.

Gelatin plate; colony irregular and developing a peculiar, characteristic, contorted mass arranged in parallel rows of thread. *A proteus-like colony.*

Gelatin stab; growth is slow, and a shallow pit is formed which in about three weeks half liquefies the gelatin, but remains to the end as a cone shaped pit.

Agar; not characteristic.

Potato; a velvety white, even *snow white*, thick growth.

Milk; curdles in two days into a soft, jelly-like mass which rapidly digests into a yellowish, cloudy liquid which is alkaline. Butter made from cream ripened with this organism has but little taste and what taste it has is unpleasant.

No. 153. (Not common.)

Morphology; size, 1.2μ by 3μ to 6μ, with blunt ends. Threads not long and frequently broken.

Gelatin plate; a large colony, 1 cm. in diameter, uniformly granular, with a radiating rim.

Gelatin stab; a deep funnel formed with liquid at bottom and an air space at the top. The liquefaction increases and a broad cone of slightly cloudy liquid is produced with a scum. Later the liquid becomes clear and the scum dense.

Agar; white, opaque and moderately thick. The growth is tough and not easily broken into fragments.

Potato; a *ground glass, much folded layer is produced with liquid under the folds.* Later the folds increase and the whole becomes white.

Milk; curdles rapidly at 20° and 36° into a hard curd and no whey. Alkaline. Digests into a clear, yellowish liquid.

Division B.

Spores at one end of the rod.

No. 189. (Rare.) *B. arborescens lactis II.* (n. sp.)

Morphology; size, .8μ by 4μ. The spore is 1μ by 1.2μ. Occasionally two or three rods together, but no chains.

Gelatin plate; colonies become 1 cm. in size or larger, showing radiating fibers *strewn with knots.* The fibers themselves are fine and branching. The knots look like isolated colonies and each frequently shows secondary radiation. Fibers grow mostly under the surface. Very characteristic.

Gelatin stab; an arborescent growth underneath the surface of the gelatin. Branches extending horizontally from the needle track and ending in knobs. In two days a dry pit is formed on the surface with numerous disjointed colonies extending from this pit to the edge of the tube. Later liquefies at the surface with a dense white cloudy liquid.

Agar; surface curdled completely with a thin, hardly visible growth.

Potato; thin and scanty growth.

Bouillon; a tough scum is formed which sinks while disturbed and forms a flocculent sediment. Later the scum sinks and the liquid is slightly cloudy.

Milk; no effect produced upon milk.

Division C.

Bacilli with two spores, one in either end.

The following species is certainly peculiar. The rods are very long, from 2μ to 6μ, and in each end of the rods may frequently be seen a clear unstained body. I have regarded them as spores, even though it has generally been thought that a bacillus with two spores has not been found. At all events this species is very unlike any other found and may be most easily recognized from this apparent double spore formation. I have therefore placed it in a division by itself with a distinct specific name.

No. 190. (Rare.) *B. dispora lactis.* (n. sp.)

Morphology; size, 1.8μ by 2μ to 6μ. Spores are about 1μ to 1.5μ, variable in size. Long chains of threads are formed with rounded or tapering ends, like a string of sausages.

Gelatin plate; a round, tough colony is produced, yellowish in color, *easily removed intact by a platinum loop.* When reaching the size of 1 mm. it sinks into a slowly liquefying pit, but the mass of bacilli remain as a distinct nucleus for a long time, the liquid being clear.

Gelatin stab; a shallow funnel is formed and the liquefaction becomes complete.

Agar and potato; not characteristic except that both show a tendency to have isolated clumps rather than a uniform layer.

Milk; at 20° is curdled and rendered amphoteric or alkaline. A slight digestion is apparent.

The following list is an index to the pages on which the different organisms are described. The species which I have named or have identified with species named by other investigators are given by name as well as by number; the others by number only. In accordance with general usage the new species are indicated by the abbreviation n. sp.:

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DISCUSSION OF THE TERMS DIGESTIBILITY, AVAILABILITY AND FUEL VALUE.

BY W. O. ATWATER.

In order to make food available for use in the body it must be digested. The digestion is done at the expense of a certain amount of material which the food itself must supply. This material is essentially that which is poured into the alimentary canal in the digestive juices. That which is not re-absorbed remains in the feces in the so-called metabolic products. These latter include also the fragments of intestinal ephithelium and minute quantities of other substances. In addition a small part of the food escapes digestion. The feces are, accordingly, made up of (1) metabolic products which are mainly the residues of digestive juices and (2) the undigested residues of the food.

DIGESTIBILITY AND AVAILABILITY OF NUTRIENTS.

This brings out the distinction between the terms digestibility and availability as they are here used.

Digestibility.—This term is here used to designate the quantity or proportion of material digested. It is measured by the difference between the total food and the undigested residue. The statement applies likewise to the several nutrients—protein, fats, carbohydrates and mineral matter. To determine the amount of each which is digested the total amounts in the food and the corresponding amounts in the feces are determined, and the latter are subtracted from the former. The methods for distinguishing between the metabolic products and the undigested residue of the food have not been made sufficiently accurate to enable us to determine exactly the proportion actually digested.*

Availability.—The term availability is here used to designate the quantity or proportion of the food and of the several nutrients which can be used for the building and repair of tissue and the yielding of energy. The metabolic products, which come from the digested food, are not used for either building

* See Report of this Station for 1897, p. 157.

material or fuel, and hence are not available in the sense in which the word is here employed. The amounts of available nutrients are found by subtracting the ingredients of the feces from the corresponding ingredients of the food. The term digestible has often been used in this sense, but the distinction here made is evidently an important one. How the available nutrients of the food are actually utilized in any given case; how much benefit the body gains from a given amount of nutrients in any given diet, is another matter.

AVAILABILITY OF ENERGY.

We have spoken of the metabolic products as residues from materials used to digest the food and thus make it available for general uses. Their energy is not metabolized. In both material and energy they represent part of the cost of making the food available. But the process of digestion involves certain mechanical operations, especially the chewing of the food and the peristaltic movement which accompanies the passage of the food through the alimentary canal. For these a certain amount of mechanical energy is required. More or less energy is still further used in the secretion of the digestive juices, and finally there are the processes of cleavage and synthesis involving more or less transformation of energy. The energy actually used in all these operations, which belong mainly to the general process of digestion, comes from the part of the food which we have designated as available. Since it is used for digestion it is not available for the other work of the body. The available energy, using the word available in the broader sense, includes the energy required for the work of digestion. This energy of digestive work has not yet been exactly measured. Reasonably close approximations have been made, notably by Zuntz and Hagemann, with domestic animals. With feeding stuffs containing large amounts of cellulose and other undigestible materials, the energy required for digestive work was found to be very large. In the digestion of straw and the poorer qualities of hay this cost of handling the coarse material which resists the action of the digestive juices is so large as to require a not inconsiderable share of the total available energy. With the concentrated feeding stuffs the amount of energy required for digestive work is much smaller.

Experiments for determining the amount of energy required for the digestion of food by man have not been made. The

materials used for the food of man, however, generally contain but very little of the undigestible material the cost of handling which is so large. The removal of the hulls of grain in the milling, and the various processes in cooking help to reduce this cost to its lowest terms.

There is, moreover, a portion of the energy of the available food which is not made available in the body at all, namely, that of the incompletely oxidized material which is excreted in the urine. This comes mostly from the protein and occurs in the forms of urea and kindred compounds. It is generally assumed that the available fats and carbohydrates of the food are, under normal conditions, completely oxidized in the body. Accordingly, their available energy is their total heat of combustion. The available energy of protein, on the other hand, is taken as the difference between the total heat of combustion and the heat of combustion of the water-free substance of the corresponding urine. This subject is discussed in the following article, pages 99 and 100.

This view makes the total available energy of the food the total energy (heat of combustion) less that of the corresponding unoxidized residues of the feces and urine. It is also the total energy of the available nutrients less that of the corresponding unoxidized material of the urine. We might deduct from the total available energy the amount required for the mechanical work of digestion and other operations by which the food is prepared for use, and call the difference the net available energy, but it does not seem necessary here to insist either upon this distinction or upon the corresponding one which would separate the nutrients oxidized for this purpose from the rest of the available nutrients.

FUEL VALUE.

The term fuel value is here used to designate the value of the food for its service as fuel. Exactly how this service is rendered is not yet known. Without discussing the question as to how much of the potential energy of the food is transformed directly into heat in the body, or what proportion is first used for internal muscular work and afterwards transformed into heat, we may for our present convenience assume that the chief uses of the nutrients of food as fuel are to:—

1. Yield energy as heat.
2. Yield energy for muscular work.

3. Protect the materials of the body or of other food from consumption by being oxidized; in other words, to:—
   a. Protect protein of the body or of food from oxidation.
   b. Protect fats (and carbohydrates) from oxidation.

We may also distinguish between what might be called the physical and the physiological fuel value. The physical fuel value would be the total energy made kinetic in the body, and would be measured by the heat of oxidation of the material burned. The physiological fuel value would be represented by the actual benefit gained by the body from the use of the fuel for the different purposes which it serves. Thus the actual value to the body of the energy from a gram of fat may be, and is by some physiologists held to be, less when used for mechanical work than if used as heat. To what extent the physiological and the physical fuel values agree or disagree is not yet known. For the present purpose the term fuel value is here applied to the physical value.

DEFINITIONS.

What has thus been explained may be summarized in the following definitions.

Digestibility.—This term is used to designate the quantity or percentage of a given amount of food or of a given nutrient which is digested, *i. e.*, rendered capable of absorption, and, under normal conditions, actually absorbed from the alimentary canal.

Availability.—This term is used to designate the quantity or percentage of a given amount of food or of a given nutrient which is capable of being utilized for the forming of tissue and yielding energy. It is the total material less the corresponding material of the feces.

Fuel value.—By this is understood the energy (heat of combustion) of the material of the food which is oxidized, *i. e.*, capable of oxidation in the body. For the total food it is the total energy less that of the corresponding unoxidized materials of the feces and urine. For the protein it is likewise the total heat of combustion less that of the corresponding unoxidized residues of these excretions. For the fats and carbohydrates it is the total energy less the energy of the corresponding unoxidized material of the feces.

THE AVAILABILITY AND FUEL VALUE OF FOOD MATERIALS.

BY W. O. ATWATER AND A. P. BRYANT.

INTRODUCTION.

The Storrs Experiment Station has devoted considerable attention to the study of the food and nutrition of man. Not only are such studies authorized by the Act of Congress establishing the Stations, but the Legislature of Connecticut makes a special appropriation to the Station for the purpose, and the Station coöperates with the U. S. Department of Agriculture in these inquiries. The lines of research followed by the Station have included the analyses of a large number of food materials, the carrying on of a considerable number of studies of actual dietaries of people of different classes in Connecticut, the determination of the proportions of nutrients in food of mixed diet which are actually digestible and available for use in the body, and the study of the fundamental laws of nutrition by experiments with men in the respiration calorimeter.

The purpose of the present article is to summarize* some of the results of these studies, and of similar investigations elsewhere, in their bearing upon the availability and fuel value of different food materials or classes of food materials to the human body. To this end recourse has been had to (1) the data obtained from a compilation of over 4,000 analyses of American food materials; (2) results arrived at by different American and European investigators concerning the heats of combustion and fuel values of different chemical compounds, groups of compounds and kinds of food materials; and (3) the statistics of over 100 digestion experiments, and over 200 dietary studies carried out in the United States.

* A more extensive treatment of this subject is being prepared for publication elsewhere.

THE NUTRIENTS OF FOOD.

For the maintenance of life and activity the human machine requires material for the building and repair of its parts and for combustion to furnish heat and the energy required for external and internal muscular work. It is customary to classify the nutrients of the food into four groups—protein, fats, carbohydrates, and mineral matter or ash.

PROTEIN—NITROGENOUS NUTRIENTS.

The term protein is commonly applied to all the nitrogenous nutrients in the food with the exception of the nitrogenous fats. It includes a number of widely different groups of compounds with correspondingly different nutritive values. The protein compounds may be roughly divided into three groups. The first will include the most important of the nitrogenous nutrients, such as albumen of meat and egg, casein of milk, myosin of meat, gluten of wheat, etc., all of which are sometimes grouped together as albuminoids. With these may be grouped also the so-called gelatinoids, such as chondrigen, gelatin, etc., derived from animal connective tissue. The members of this latter class are by some writers called proteids and by others albuminoids. Both of these classes are, in this article, grouped together as proteids. Distinguished from these are the third group, the non-proteids, including the creatin, creatinin and other so-called extractives of meat, and the amids, etc., of vegetable foods.*

Sources and uses.—Protein is found in greater or less amounts in nearly all food materials, except the pure fats, sugars, and starches. The chief sources are meats, fish, eggs, and milk among the animal, and the legumes and cereals (beans and peas, wheat, corn, etc.) among the vegetable food materials. The garden vegetables and fruits furnish a very small amount of protein, and even this has a low nutritive value on account of its large proportion of non-proteids. The protein of animal foods and the cereal grains is very largely composed of true proteids. Only these, and especially those here called albuminoids as distinguished from the so-called gelatinoids, are

* See discussion of this subject, with reference to authors, in U. S. Dept. Agr., Office of Experiment Stations, Bul. 65, p. 18. The terminology here employed is that adopted provisionally by the Association of American Agricultural Colleges and Experiment Stations.

capable of being transformed into nitrogenous body tissue, and thus go to form the blood, muscle, tendon, brain, nerves, etc. The non-proteids appear to have but little nutritive value, unless it be in some cases, for fuel. It may be that some of them have an especial value as sparers of protein, *i. e.*, for protecting the protein of food or body tissue from consumption. But too little is known of their functions to warrant very definite assumptions.*

Proportion of proteids and non-proteids.—In analyses of food materials by current methods it is the almost universal practice to take the product obtained by multiplying the total nitrogen of the food by 6.25 as a measure of the total nitrogenous material, *i. e.*, protein; in other words, to assume that protein contains 16 per cent. nitrogen. This involves two errors. In the first place the proportion of nitrogen in the non-proteids taken collectively is greater than in the proteids, and multiplying the nitrogen by 6.25 gives a value generally greater than the actual amount of nitrogenous material. In the second place the non-proteids have little nutritive value. Both these errors, therefore, tend to make the estimate of nutritive value too large. It would perhaps be better to leave the non-proteids out of account in estimating the nitrogenous, *i. e.*, tissue-forming material of food. Unfortunately our present chemical methods for the separation of the proteids and non-proteids in food materials are unsatisfactory. The comparatively few determinations now on record of the proportions in a given food material do not accord with each other and cannot be considered reliable. Until exact information concerning the proportion of proteids and non-proteids in different classes of food materials is obtained recourse must be had to the best data available. In flesh the proportion of non-proteids, *i. e.*, so-called extractives or meat bases, appears to be larger than has sometimes been supposed, but the data upon the subject are very inadequate.

The nitrogen in the cereal grains and their manufactured products is, like that of meats, mostly in the form of proteids, although a small proportion exists in the form of amids, of

* It has been suggested that asparagin may serve as nitrogenous nutriment for the intestinal bacteria and thus protect the proteids which might otherwise be broken down.

which asparagin may be taken as the type. The data concerning the proportions of these different nitrogenous compounds are few, but it appears from the work of Teller[1], Snyder[2], Wiley[3], and others that not less than 96 per cent. of the nitrogen of the seeds of cereals (and probably the legumes) may be assumed as present in proteid combinations, and not over 4 per cent. in non-proteid combinations.

While the proportion of non-proteids in animal foods and in the cereal grains and their manufactured products is relatively small, the quantity in vegetables and fruits is at times large, so that in some cases as much as two-thirds of the total nitrogen may occur in non-proteid forms. The methods of separation are too unsatisfactory and the amount of data too small and conflicting to enable us to estimate the exact proportion of proteid and non-proteid nitrogen in the different vegetables and fruits. From the best information available we are led to the rough estimate that, in round numbers, 60 per cent. of the nitrogen in vegetables such as potatoes, turnips, cabbage, lettuce and the like, and 70 per cent. of that in fruits occurs in proteid combinations.

The nitrogen factor of protein.—It has already been pointed out that the portion of nitrogen in protein compounds varies considerably. It has for a considerable time been the general custom to assume an average of 16 per cent. of nitrogen in protein, including both proteids and non-proteids. In other words the total nitrogen has been multiplied by the factor 6.25 to obtain the amount of protein in the given material. The proteids of muscular tissue, such as are found in ordinary meats, appear to contain, in general, about 16 per cent. and the non-proteids of such tissue a somewhat larger proportion of nitrogen. However, neither the amount of these non-proteids nor their proportion of nitrogen seems to be sufficient to cause any large error in the use of the factor 6.25 for estimating the total protein.* In the flesh of some kinds of fish, as the cod and more especially the skate, the total nitrogenous material seems to

1. Arkansas Exp. Sta., Bul. No. 42, p. 100.
2. Minn. Exp. Sta., Bul. No. 63, p. 528.
3. U. S. Dept. Agr., Division of Chemistry, Bul. 13, Part IX., p. 1247.

* This view is confirmed by the results (unpublished) of recent investigations by Prof. Grindley, Univ. of Illinois, in coöperation with the U. S. Dept. Agr.

contain more than 16 per cent. nitrogen.* It is probable that on the whole the factor 6.25 gives a tolerably accurate measurement of the protein of fish. The same is doubtless true of eggs. The protein of cow's milk, according to the small number of reliable investigations now available, appears to contain a trifle less than 16 per cent. of nitrogen, but hardly enough to warrant at present the use of any other factor than 6.25. It seems best, therefore, to retain this factor for the protein of all common animal food materials.

The proteids of the cereal grains appear to contain on the average more than 16 per cent. of nitrogen. The proportion in different cereals has been the subject of study by a number of investigators, notably Osborne† in this country and Ritthausen‡ in Europe. Ritthausen in a review of this subject in 1896 summarized the results of inquiry up to that time regarding the proportions of nitrogen in different proteids. He grouped the cereals according to the average proportion of nitrogen in the total protein matter, making three classes, those containing approximately 17.5, 16.7 and 16 per cent. nitrogen respectively, or in other words, those in which the protein is computed by multiplying the nitrogen by the factor 5.70, 6.00 and 6.25 respectively. Wiley§ has reviewed the work of Osborne upon the proteids of the different cereals and arrived at factors for the calculation of the protein in these products not materially different from those of Ritthausen. The grouping in Table 2 on page 79 conforms with the conclusions reached by these two investigators.

We have found extremely few satisfactory data concerning the composition of the proteids of vegetables and fruits. In lack of more definite information concerning the exact proportion of nitrogen it seems best for the present to retain the customary factor, 6.25, for calculating the proteids, and, taking asparagin as the type of the non-proteids, to use the factor 4.7|| for estimating their amount.

The factor for estimating the total nitrogenous matter or protein from the total nitrogen will thus depend upon the

* In the flesh of the skate this may perhaps be due to the accumulation of urea or allied compounds in the tissues.

† Reports Conn. Agr. Exp. Sta., 1890, *et seq.*

‡ Landw. Vers. Stat. 47 (1896), p. 391.

§ U. S. Dept. Agr., Division of Chemistry, Bul. 13, Part IX., pp. 1171–1192.

|| Asparagin contains 21.2 per cent. nitrogen.

proportions of proteids and non-proteids as well as upon the percentages of nitrogen in each. In the animal foods and in the cereal grains the difference between the amounts of true proteids and the amounts of protein, which include in addition the non-proteids, is so small that little error is introduced in multiplying the total nitrogen by the factor for the proteids in estimating the total protein. In considering the nutritive value of the nitrogenous matter of the vegetables and the fruits, however, the case is quite different, since the non-proteids appear to form something like one-fourth of the total nitrogenous matter. Indeed, in view of the fact that the protein is commonly taken as the measure of the tissue forming material of the food, it might be more nearly correct to consider simply the proteids in the vegetables and fruits, either leaving the non-proteids out of account entirely or including them with the fats and carbohydrates as fuel ingredients. But since some of the non-proteids occurring in vegetables may have a special value as protectors of the protein of the body or of food from consumption there is a partial excuse for including them in the estimates for protein of these foods until more exact information regarding their composition and nutritive values shall accumulate.

The nitrogen factor for vegetables and fruits, however, will be quite different from that for animal foods or for cereal products. If we suppose that 60 per cent. of the nitrogen of the vegetables is in proteid combination and 40 per cent. in non-proteid combination we may calculate the nitrogen factor in the following manner: One gram of nitrogen may be considered as representing .6 gram in proteid and .4 in non-proteid combination. The proteids corresponding to the .6 gram of nitrogen would be found by multiplying .6 by 6.25 and would amount to 3.75 grams. The .4 gram of non-proteid nitrogen may be assumed to exist in forms equivalent to asparagin containing 21 per cent. of nitrogen, corresponding to a protein factor of 4.7. This would give ($.4 \times 4.7 =$) 1.88 grams of non-proteids. The 1 gram of nitrogen would thus correspond to ($3.75 + 1.88 =$) 5.63 grams of protein. For the present purpose we may assume that one gram of nitrogen in vegetables corresponds to approximately 5.65 grams of protein. This makes the nitrogen factor 5.65. In a similar way the factor

for calculating protein from the nitrogen of fruits is found to be 5.80.

In ordinary tables of percentage composition the values for protein in vegetables and fruits are calculated by use of the factor 6.25, which evidently gives too large results. It naturally follows that the figures for carbohydrates, which are obtained by difference, *i. e.*, by subtracting the sum of the percentages of protein, fat, ash and water from 100, are too small by a corresponding amount. It is easy to compute the quantities of protein according to the factors above assumed from the quantities according to the factor 6.25 by multiplying by certain constant values. Thus protein as N. × 6.25 may be converted to protein as N. × 5.70 by multiplying by .912 and to protein as N. × 6.00 by multiplying by .950.

The following table gives the factors here proposed for calculating the amounts of protein in different groups of food materials from the total nitrogen. In addition the factors for changing protein as N. × 6.25 to protein as N. × 5.70, 6.00, etc., are given. Where protein is changed from one basis to another, however, the difference between the old and the new value must be added to the carbohydrates.

TABLE 2.

Proposed nitrogen factors for the protein of different groups of food materials.

KIND OF FOOD MATERIAL.	Factors here proposed.	Factors for computing protein according to proposed factors from protein as N. × 6.25.
Animal foods, - - - - - -	6.25	—
Wheat, rye, barley, and their manufactured products, - - - - -	5.70	.912
Maize, oats, buckwheat, and rice, and their manufactured products, - -	6.00	.960
Dried seeds of legumes, - - - -	6.25	—
Vegetables, - - - - - - -	5.65	.904
Fruits, - - - - - - -	5.80	.928

FATS AND CARBOHYDRATES—FUEL INGREDIENTS.

The fats and carbohydrates in the food may be considered together in view of their similarity of use in the body. Their function is mainly that of fuel to yield energy for warmth and

muscular work. Unlike the proteids they cannot form nitrogenous tissue, though they are contained and stored in the fluids and tissues of the body. Thus large amounts of fat are stored in adipose or fatty tissue where it forms a reserve supply of fuel for future use. Both the fats and the carbohydrates, by being themselves consumed, spare the more essential and costly nitrogenous matter of food and body tissue from consumption.

PROPORTIONS OF NUTRIENTS SUPPLIED BY DIFFERENT GROUPS OF FOOD MATERIALS IN THE AVERAGE DIET.

In discussing the availability and fuel value of the nutrients of food we have to consider not simply the individual food materials or the groups into which the food materials may be classified, but also the proportions of these individual materials and groups in the average diet. What we wish to get at is the nutritive value of each kind of food as it is actually eaten as part of a mixed diet. Thus in certain digestion experiments milk has been found to be more completely digested and thus more fully utilized when it is taken with bread than when it formed the sole diet. Furthermore different food materials or nutrients of different food materials differ considerably in digestibility and availability even when the conditions for utilizing them are most favorable. If we wish to obtain figures for the average availability and fuel value of protein, fats and carbohydrates of ordinary diet we must know not only the availability and fuel value of each of the different kinds or classes of food materials, but also the proportion in which these occur in the diet and the proportions of the total protein, fats and carbohydrates that are obtained from each. These can be learned only by careful examination of a large number of dietary studies. Fortunately the results of some 250 such studies carried on in this country are now on record. Of these 185 seem to the writers to be of such character as to warrant including them in making general estimates of the proportions of the different kinds or groups of food materials in the average diet and the proportional amounts of the different nutrients furnished by each group in the whole diet.

In examining the 185 studies they are first divided into classes according to the occupation of the persons studied. The majority of the studies were of families of day laborers, mechanics, farmers, professional men, etc. There were also a number of dietaries of boarding houses and of college students' clubs, and a few of individuals or special groups of persons, especially of athletes, as rowing crews, foot-ball teams and bicycle racers. They were made in different parts of the United States, from Maine to California. All belong to the nutrition investigations which have been carried out for some years past under the auspices of the U. S. Department of Agriculture by investigators connected with a considerable number of educational and scientific institutions.*

The food materials used in each dietary were divided into the following groups:

Beef and veal,	Corn meal, rye and buckwheat flour,
Mutton and lamb,	Oat meal, rice and wheat preparations,
Pork,	Wheat flour, bread, crackers, pastry, etc.,
Poultry,	Starch,
Fish,	Sugar,
Eggs,	Dried legumes,
Butter,	Potatoes and sweet potatoes,
Cheese,	Other vegetables,
Milk and cream,	Fruits.

The published statistics of each study show the total weights of the nutrients—protein, fats and carbohydrates—in each food material in each dietary. From these data the total weights of nutrients in each group of food materials were found. From these figures for total weights of protein, fats and carbohydrates in the different groups—beef and veal, dairy products, cereals, vegetables, etc., there were computed the percentages which these weights formed of the total amount of protein, fats and carbohydrates in the diet. In a similar manner the statistics of the total food materials in each dietary were used for calculating the percentages of the whole occurring in each group of materials.

Having thus found the proportion of total foods and the different nutrients that were furnished by the different kinds or groups of food materials in each dietary, the averages

* The original data are to be found in the Nutrition publications of the Office of Experiment Stations and in the Reports of this Station.

were compared for all the dietaries of each class and finally for all the 185 dietaries. These final averages are shown in Table 3.*

TABLE 3.

Relative proportions of total food and of total nutrients supplied by different groups of food materials in average of 185 dietary studies.

KIND OF FOOD MATERIAL.	Total Food.	Protein.	Fat.	Carbo-hydrates.
	%	%	%	%
Beef and veal,	10.3	24.6	19.5	—
Mutton and lamb,	1.4	3.3	3.8	—
Pork,	5.4	8.8	30.0	—
Poultry,	1.1	2.6	1.2	—
Fish, shell fish, etc.,	1.9	3.7	.8	.1
Total meat, etc.,	20.1	43.0	55.3	.1
Eggs,	3.0	5.9	4.3	—
Butter,	1.9	.2	19.7	—
Cheese,	.4	1.6	1.6	—
Milk and cream,	19.9	10.5	10.7	5.3
Total dairy products,	22.2	12.3	32.0	5.3
Total animal food,	**45.3**	**61.2**	**91.6**	**5.4**
Cornmeal, rye, and buckwheat flour,	1.8	1.9	.4	5.2
Oatmeal, rice, and wheat preparations,	1.3	2.1	.6	3.6
Wheat flour, bread, crackers, pastry, etc.,	18.7	26.5	6.0	45.9
Total cereal products,	21.8	30.5	7.0	54.7
Starch,	.1	—	—	.2
Sugar,	5.5	—	—	21.0
Dried legumes,	.6	2.0	.1	1.3
Potatoes and sweet potatoes,	13.7	3.9	.3	10.0
Other vegetables,	7.4	1.8	.4	2.5
Total vegetables,	21.1	5.7	.7	12.5
Fruits,	5.6	.6	.6	4.9
Total vegetable food,	**54.7**	**38.8**	**8.4**	**94.6**
Total food,	**100.0**	**100.0**	**100.0**	**100.0**

It thus appears that, in the average of these 185 dietaries, not far from 43 per cent. of the protein was furnished by meats

* The detailed figures from which the averages are computed will probably be given with a more complete discussion of the subject in a Bulletin of the Office of Experiment Stations.

and fish, 6 per cent. by eggs and 12 per cent. by dairy products, making a total of 61 per cent. from animal food materials. Of the remaining 39 per cent. which came from the vegetable food materials, 30 per cent. was supplied by the cereals, 2 per cent. by the dried legumes, 6 per cent. by garden vegetables including potatoes, and 1 per cent. by fruits. More than 90 per cent. of the fat was of animal origin, and more than half came from meats, while nearly one-third was furnished by dairy products. On the other hand only a little over one-twentieth (5.5 per cent.) of the carbohydrates was of animal origin, while 55 per cent. came from the cereal products. It is a little surprising to note that over one-fifth of the total carbohydrates in these 185 dietaries studied was furnished by cane sugar, molasses, etc.

How closely these figures represent the average diet it is impossible to say. There is a large proportion of the population of the southern states, including the bulk of the colored people and of the poorer whites in the country districts, who live mainly upon corn meal, fat pork and molasses. A considerable number of dietaries of the people of these districts have been studied, but they are not included in the 185 studies above summarized. There may be other exceptions also, but it seems to us probable that these figures in Table 3 are not very far from a fair representation of the actual distribution of the different food materials and nutrients in the average diet of persons of the industrial, commercial, and professional classes in the United States.

THE AVAILABILITY OF THE DIFFERENT CLASSES OF NUTRIENTS IN FOOD OF MIXED DIET.

The value of food for nutriment depends not only upon the total amounts of nutrients but also upon the amounts which the body can make available for its support. The proportions of the different nutrients which the body can digest and utilize from different food materials are learned by digestion experiments. Such experiments involve the accurate measurement of the amounts of the different kinds of nutrients consumed in the food during a given period and the corresponding amounts excreted in the feces. This last material is made up of the

undigested residue of the food, and of the so-called metabolic products. The latter consists mainly of residues of the digestive juices. Later research has shown that in man the actual amount of undigested nutrients makes up relatively a much smaller portion of the intestinal excretion than was formerly supposed. Indeed some investigators are inclined to take the ground that the nutrients in ordinary food materials, properly prepared, are almost wholly digested by persons in health, and that the solid excreta are almost entirely made up of the so-called metabolic products and residues from the alimentary canal.* While the feces do not give an exact measure of either the actual amount of the different nutrients which remain undigested in their passage through the alimentary canal or of the amounts of digestive juices used for the digestion, they do give us a measure of the availability of the food for use in the body. If the same quantities of two different food materials require the same amounts of digestive juices to prepare them for absorption, but the first is more completely digested, *i. e.*, leaves less undigested residue than the second, the first is more available. So likewise if both are equally digestible but the former requires more of the digestive juices to digest it, it may be regarded as really supplying a less amount of available material to the body.

The experimental data as to the digestibility of different kinds of nutrients in different classes of food materials are as yet limited. There are on record a considerable number of digestion experiments with men. In some of these single food materials were used. In others an ordinary mixed diet of more or less varied character was employed. The experiments with single food materials or with very simple mixed diet give data for estimating the coefficients of availability of the nutrients of individual food materials. From such data we have prepared tentative coefficients for the availability of the nutrients of a number of the more common kinds of food materials such as meats, milk, wheat bread, potatoes, etc. It is, however, a question whether these coefficients could be correctly applied to the same food materials when they are eaten in the

* See discussion of this subject in Storrs Reports, 1896, p. 163 and 1897, p. 154. This matter will also be discussed in more detail in a future bulletin of the Office of Experiment Stations of the U. S. Department of Agriculture.

usual way as components of an ordinary mixed diet. Fortunately we have a means for obtaining a reasonably definite idea as to their accuracy under the latter conditions. There are now on record the results of about 100 American digestion experiments with men on mixed diet. Most of these were conducted by Prof. C. E. Wait at the University of Tennessee, Knoxville, and by the writers and associates. In these experiments 13 persons have served as subjects. The diet in each case was simple and made up of common food materials, and was entirely normal in amount, proportions of ingredients and method of cooking. In each experiment the ingredients of the feces were compared with the total amounts of nutrients in the food. The coefficients of availability thus obtained apply therefore to the total food eaten and not to the individual food materials. Now if the coefficients of availability which were assumed for the different kinds of food materials as above described represent the actual availability of the same materials when they are eaten in mixed diet, then by applying them to the materials consumed in these experiments we should get estimated results which would agree with those found by experiment. We may therefore use the agreement or disagreement of the estimated availability of the total nutrients of the diet used in these experiments with the results actually found as a measure of the correctness of the assumed coefficients of availability. This has actually been done. Using the coefficients as first assumed there was some discrepancy between the computed and experimental results. The coefficients were slightly altered, the change being such as seemed to us most probably correct and the computations were repeated. In this way coefficients were found which brought results agreeing very closely with those of actual experiments.

In selecting coefficients for availability, food materials were divided into the following groups: (1) Animal food materials, as meats, fish, milk, etc. (2) Cereals such as wheat flour, corn (maize) meal, etc. (3) Sugars and starches. (4) Vegetables, as potatoes, cabbage, turnips, etc. (5) Fruits.

The coefficients of availability assumed are shown in the following table.*

* The details of the calculations of which this and the following tables summarize the results will probably appear in a Bulletin of the Office of Experiment Stations.

TABLE 4.

Coefficients of availability of nutrients of different groups of food materials and of total nutrients of mixed diet.

	Protein.	Fats.	Carbohydrates.
	%	%	%
Animal foods,	97	95	98
Cereals,	85	90	98
Legumes, dried,	78	90	97
Sugars and starches,	—	—	98
Vegetables,	83	90	95
Fruits,	85	90	90
Vegetable foods,	84	90	97
Total food,	92	95	97

In applying the assumed factors for availability (coefficients of availability) to the results of actual digestion experiments with men upon mixed diet the method employed was in brief as follows: The amount of available protein, for example, was calculated upon the assumption that 97 per cent. of the protein in animal food, 85 per cent. of that in cereal food, 78 per cent. of that in the dried legumes, 83 per cent. of that in vegetables and 85 per cent. of that in fruits can be utilized by the body. The sum of the amounts of protein thus computed as available in the different groups divided by the total amount of protein in the food eaten gives the calculated coefficient of availability. The computed coefficients of availability for the fats and carbohydrates were obtained in a similar manner.

The average variations between the coefficients as found and as calculated are inconsiderable. In some individual experiments they reached 5 per cent. for one or more nutrients. In some cases the calculated values were larger, in others they were smaller than those found by experiment. These variations in individual experiments are not at all surprising. Different specimens of the same food material may differ in availability with differences in composition and method of cooking, just as different persons may vary in their capacity to digest the food. But these minor variations disappear in the average of a large number of experiments, as is seen in the figures for all the experiments together. In the whole 93 experiments averaged in the above table the coefficients for the availability of protein were 93.3 as found, against 93.6 as

calculated; the corresponding figures for the fats were 95.0 against 94.5, and for carbohydrates 97.7 against 98.1. These agreements seem to us to be reasonably close.

Table 5 gives a summary of the calculated availability of the different nutrients in 93 digestion experiments with the coefficients found by actual experiment.

TABLE 5.

Summary of comparison of coefficients of availability as found by actual experiment and as calculated by the proposed factors for availability.

No. Experiments Averaged.	EXPERIMENTS.	PROTEIN.		FAT.		CARBOHYDRATES.	
		Found.	Calculated.	Found.	Calculated.	Found.	Calculated.
		%	%	%	%	%	%
	At Middletown, Conn.						
6	Metabolism experiments (1), 1896–7,	93.2	92.2	96.7	94.7	98.4	97.5
12	Preliminary to metabolism experiment (1), 1898–9, - - -	92.5	93.3	93.7	94.3	97.7	97.9
14	Metabolism experiments (1), 1898–9,	93.9	93.5	94.8	94.3	97.9	98.0
	At Knoxville, Tenn.						
9	Digestion and metabolism experiments (2), 1896–7, - -	93.9	93.8	94.6	94.6	97.2	98.1
23	Digestion and metabolism experiments (2), 1897–8, - -	94.4	93.8	96.2	94.6	97.4	98.2
24	Digestion and metabolism experiments (2), 1898–9, - -	92.3	94.0	94.9	94.4	97.8	98.3
5	Miscellaneous experiments (3), -	91.8	92.2	93.6	94.3	97.9	97.4
93	Average of all above experiments, -	**93.3**	**93.6**	**95.0**	**94.5**	**97.7**	**98.1**

(1) With men in respiration calorimeter.

(2) With men at work and without active muscular work.

(3) With men, Minneapolis, Minn., Knoxville, Tenn., and Middletown, Conn.

It may be that these figures by themselves give an exaggerated idea of the accuracy and value of such computations. There is more or less guess work in the method of estimating the coefficients of availability. It may be largely a matter of coincidence that these particular figures bring results agreeing so closely with those of actual experiment. It may be, for instance, that some of the coefficients of availability of individual nutrients of the different kinds of food materials are really wide of the mark and that the agreements which are so

close in these particular instances are due to an accidental balancing of errors. We do not assume that the coefficients of Table 4 represent the actual availability of the nutrients of the different kinds of food materials under all circumstances or in all of the food materials of any given class. It does seem to us, however, that such comparisons as those in Table 5 indicate that these coefficients represent a reasonably close approximation to the actual availability in the average mixed diet.

HEATS OF COMBUSTION OF NUTRIENTS.

The potential energy of any given substance is usually taken as equivalent to its heats of combustion determined by burning a known weight of the substance in oxygen. The actual amount of energy which the body can obtain from a given food material or diet depends upon various factors, the chief of which are the amounts and potential energy of the available nutrients of the food and the amount of incompletely oxidized material rejected in the urine.

The heats of combustion of a very large number of individual food materials have been determined, but the data concerning the heats of combustion of definite chemical compounds occurring in the food of man are much more limited. It is to Stohmann, Berthelot, and their associates that we are indebted for by far the greater part of the data now available, although within a few years a considerable number of determinations have been made in this country, mostly in connection with the nutrition investigations carried on under the auspices of the U. S. Department of Agriculture.*

HEATS OF COMBUSTION OF PROTEIDS, NON-PROTEIDS, AND PROTEIN OF FOOD MATERIALS.

The heat of combustion of different proteids varies within certain limits, but is in all cases much larger than that of the

* See summaries of results of these inquiries as given by Stohmann, U. S. Dept. Agr., Experiment Station Record, Vol. VI., p. 590; by Berthelot in Thermochimie, Vol. II., and by Atwater in Bulletin No. 21, U. S. Dept. Agr., Office of Experiment Stations.

It is expected that details of a compilation of the heats of combustion of different compounds and groups of compounds occurring in food materials will be published in the near future in a Bulletin of the Office of Experiment Stations.

more common non-proteids. The heat of combustion of the protein of any given food material will depend to some extent upon the kinds of proteids and of non-proteids which furnish the nitrogen from which the protein is estimated, but more especially upon the proportion in which these two classes of compounds occur, and unless we have direct data concerning the heat of combustion of the protein this value must be computed after much the same method as was adopted in estimating the nitrogen factor for protein (see pages 76–80).

The heat of combustion of fat-free muscular tissue, from which the extractives, *i. e.*, the non-proteids, have been removed, gives us a tolerably good idea of the potential energy of the protein of meats. The average value obtained for such protein is about 5.65 calories per gram. The heat of combustion of meat proteids appears to be noticeably higher, averaging not far from 5.75 calories per gram. Creatin may be taken as a type of the non-proteids of meats with a heat of combustion of 4.27 calories per gram. If we had satisfactory data concerning the proportions of creatin and other extractives in muscular tissues we could calculate the energy per gram of meat protein, but at present the heat of combustion of fat-free muscular tissue from which the extractives have not been removed gives us the most satisfactory value for this quantity. Concerning the heats of combustion of the proteids or protein of fish we have almost no data. It is assumed in this article that their heat of combustion is practically the same as that of the corresponding compounds in meats. Eggs are commonly assumed to have less of non-proteids than meats, and the heat of combustion would naturally be larger. The average heat of combustion of egg albumin appears to be about 5.70, and of protein of the nitrogenous matter of the yolk 5.80 calories per gram. It is probable, therefore, that the heat of combustion of the protein of egg is not far from 5.75 calories per gram. Concerning the heat of combustion of the protein of milk the data are somewhat conflicting. Casein as prepared in different ways has a heat of combustion of from 5.6 to 5.9 calories per gram. It has been assumed in the present article that the heat of combustion of milk protein is the same as that of muscular tissue, namely, 5.65 calories per gram.

The heats of combustion of vegetable proteids must be estimated largely from those of gluten, glutenin, gliadin, legumin, and plant fibrin, which are the principal proteid compounds of vegetable origin of which we find the heats of combustion reported.* Asparagin may be taken as a type of the non-proteids of vegetable foods, with a heat of combustion of 3.45 calories per gram. The heats of combustion of the protein of vegetable food materials will depend chiefly upon the proportions of proteids and non-proteids. In computing the heat of combustion of the protein of cereals we may assume 4 per cent. of the nitrogen of cereals as occurring in non-proteid compounds (see page 76). The proteids of cereal foods may be assumed to have a heat of combustion of not far from 5.9 calories per gram. In other words, about 96 per cent. of the weight of the protein of wheat flour, maize meal, buckwheat, etc., would have a total energy value of 5.9 calories per gram and the remaining 4 per cent. a value of 3.45 calories per gram. This would make the heat of combustion of one gram of protein of cereal food materials approximately 5.80 calories per gram.†

Concerning the heat of combustion of the dried legumes we have little information. Assuming that 96 per cent. of the nitrogen of the dried legumes is in proteid and 4 per cent. in non-proteid combination, and that the heat of combustion of the proteids is that of samples of legumin which have been burned in the bomb calorimeter, namely, 5.8 calories per gram, we may assume the heat of combustion of one gram of protein of these materials to be not far from 5.70 calories per gram.‡

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* See Table 6.

† The details of the computations are as follows:

	1 g. N. = .96 g. in proteids and .04 g. in non-proteids.	
Then	.96 x 5.70 = 5.47 g. proteids x 5.90 = - -	32.3 calories,
and	.04 x 4.70 = .19 g. non-proteids x 3.45 = -	.6 calories,
or	5.66 g. protein = - - - -	32.9 calories,
and	1.00 g. protein = 5.81 calories.	

‡ The details of the computations are as follows:

	1 g. N. = .96 g. in proteids and .04 g. in non-proteids.	
Then	.96 x 6.25 = 6.00 g. proteids x 5.80 = - -	34.8 calories,
and	.04 x 4.70 = .19 g. non-proteids x 3.45 = -	.6 calories,
or	6.19 g. protein = - - - -	35.4 calories,
and	1.00 g. protein = 5.72 calories.	

It has already been shown that the relative amount of non-proteids in the protein of vegetables and fruits is large. The potential energy of the protein of these foods is therefore relatively small owing to the low heat value of the non-proteids. Assuming 40 per cent. of the nitrogen in potatoes and other vegetables to exist in non-proteid compounds of which asparagin may be taken as the type, and 60 per cent. in proteids, with a heat of combustion of 5.8 calories per gram, the heat of combustion of one gram of vegetable protein or total nitrogenous matter would be about 5.00 calories.*

Since the nitrogenous matter of fruits appears to contain proportionately smaller amounts of the non-proteids than that of the vegetables, the heat of combustion of one gram of protein will be correspondingly greater. This heat of combustion may be computed upon the assumption that 30 per cent. of the nitrogen exists in non-proteid form of which asparagin may be taken as the type, and is approximately 5.20 calories per gram.†

In the following table are given the average heats of combustion per gram of some of the proteids and non-proteids and the computed values for protein of different groups of food materials.

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* The details of the computations are as follows:

1 g. N. = .6 in proteids and .4 g. in non-proteids.
Then .6 x 6.25 = 3.75 g. proteids x 5.80 = - - 21.8 calories,
and .4 x 4.70 = 1.88 g. non-proteids x 3.45 = - 6.5 calories,

or 5.63 g. protein = - - - 28.3 calories,
and 1.00 g. protein = 5.03 calories.

† The details of the computations are as follows:

1 g. N. = .7 g. in proteids and .3 in non-proteids.
Then .7 x 6.25 = 4.38 g. proteids x 5.80 = - - 25.4 calories,
and .3 x 4.70 = 1.41 g. non-proteids x 3.45 = - 4.9 calories,

or 5.79 g. protein = - - - 30.3 calories,
and 1.00 g. protein = 5.23 calories.

TABLE 6.

Average determined heat of combustion of proteids and non-proteids and calculated heat of combustion of protein.

KIND OF MATERIAL.	HEAT OF COMBUSTION PER GRAM.	
	Determined.	Assumed or calculated.
	Calories.	Calories.
Beef, fat-free muscle,	5.65	—
Beef, fat-free muscle, extractives removed,	5.73	—
Veal, fat-free muscle,	5.65	—
Mutton, fat-free muscle,	5.60	—
Protein of meat,	—	5.65
Egg albumin,	5.71	—
Egg, protein of yolk,	5.84	—
Vitellin,	5.76	—
Protein of egg,	—	5.75
Milk casein,	5.63 to 5.86	—
Milk protein,	5.67	—
Protein of dairy products,	—	5.65
Gliadin,	5.92	—
Glutenin,	5.88	—
Gluten of wheat,	5.95	—
Legumin,	5.79	—
Plant fibrin,	5.89	—
Protein of cereals (96 % proteids),	—	5.80
Protein of legumes (96 % proteids),	—	5.70
Protein of vegetables (60 % proteids),	—	5.00
Protein of fruits (70 % proteids),	—	5.20
Gelatin,	5.27	—
Creatin, as type of non-proteids of animal foods,	4.27	—
Asparagin, as type of non-proteids of vegetable foods,	3.45	—

HEAT OF COMBUSTION OF FATS OF DIFFERENT FOOD MATERIALS.

In determining the amount of fat in a food material the substance is commonly extracted with ether. The ether extract, however, is apt to contain more or less material not actually fat and with a lower calorific value. On the other hand, with some food materials, *e. g.*, meats, with a large proportion of fat, the extraction by ether is sometimes incomplete, so that the fat obtained is less than the actual amount in the material.

The heat of combustion of the pure fats (triglycerids) of ordinary meats has been found to vary little from 9.5 calories per gram, while that of butter-fat averages not far from 9.25 calories per gram, and that of the fats and oils of ordinary vegetable foods about 9.3 calories per gram. The values for the

corresponding ether extracts are somewhat smaller. In estimating a factor for the heat of combustion of the fat in different kinds of food materials it may be assumed that the error introduced by the fact that ether extract represents other materials than fat which have a lower heat of combustion is offset by the incomplete extraction of fat, so that these two errors tend to compensate each other. In other words, taking the ether extract as a measure of the fat of food materials we may assume a heat of combustion of 9.5 calories per gram for all animal foods except dairy products, the heat of combustion of which appears to be about 9.25 calories per gram, while the vegetable fats and oils may be assumed to have a heat of combustion of 9.3 calories per gram.

The heats of combustion of different kinds of fats and oils as found by various observers and the factors here assumed for the fat of different groups of food materials are shown in Table 7.

TABLE 7.

Average determined heat of combustion of fats and oils and assumed factors for fat of different groups of food materials.

KIND OF MATERIAL.	HEAT OF COMBUSTION PER GRAM.	
	Determined.	Assumed or calculated.
	Calories.	Calories.
Beef fat,	9.50	—
Beef, "ether extract,"	9.24	—
Mutton fat,	9.51	—
Mutton, "ether extract,"	9.32	—
Pork fat,	9.50	—
Pork, "ether extract,"	9.13	—
Lard,	9.59	—
Cottolene,	9.32	—
Butter fat,	9.27	—
Wheat oil,	9.36	—
Wheat, "ether extract,"	9.07	—
Rye oil,	9.32	—
Rye, "ether extract,"	9.20	—
Maize oil,	9.28	—
Oats, "ether extract,"	8.93	—
Barley, "ether extract,"	9.07	—
Nut oil (except cocoanut),	9.49	—
Olive oil,	9.47	—
Cocoanut oil,	9.07	—
Fat of meat, fish, eggs, etc.,	—	9.50
Fat of dairy products,	—	9.25
Fat of cereals,	—	9.30
Fat of vegetables and fruits,	—	9.30

HEATS OF COMBUSTION OF CARBOHYDRATES OF DIFFERENT FOOD MATERIALS.

The ordinary meats and fish used for food contain very little of carbohydrates. Muscular tissue has a small quantity of glycogen, but in ordinary analyses it is usually not taken into account. As has already been stated, the protein as computed by the usual factor for animal foods (6.25) is probably slightly too large. On the other hand, the fuel value* of muscular tissue is not far different from that of glycogen. Hence the error involved in neglecting the glycogen in meats and fish as is ordinarily done is of little practical importance. The proportion of glycogen in the livers of animals used for food, and in oysters and other shell fish, is considerable. The amount of these food materials consumed in the ordinary diet is, however, relatively small. The heat of combustion of the glycogen can be taken at 4.2 calories per gram.

Milk contains a relatively large amount of milk sugar. The figures for heat of combustion of milk sugar now on record are not in agreement. We may take the factor 3.9 as most nearly representing the heat of combustion per gram of the carbohydrates of dairy products, and since in the ordinary diet the quantity of glycogen is relatively very small, this same factor (3.9) may be considered as an approximate average of the heats of combustion of all carbohydrates occurring in animal food materials.

The carbohydrates of the vegetable food materials consist largely of starch, sugar and fiber (cellulose), with smaller amounts of pentosans, dextrins, gums, etc. In flours and meals the carbohydrates consist almost entirely of starch. From the data available it seems probable that on the whole we shall not err greatly in assuming that 97 per cent. of the carbohydrates of cereal products is starch (and fiber), 2 per cent. dextrin, and 1 per cent. sugar. While the fiber is not as digestible as the starch, and would therefore not have as high fuel value, it occurs in such small quantities as to be of little importance in the cereal products as ordinarily used for the food of man.

The heat of combustion of starch (and fiber or cellulose) is about 4.2, that of dextrin 4.1, and that of cane sugar 3.96

* See p. 96, *et seq.*

calories per gram. Since the heat of combustion of dextrin and sugar is not greatly different from that of starch, and the amount in the cereal food materials relatively small in amount, the heat of combustion of the carbohydrates of these materials may be taken at 4.2 calories per gram.

The carbohydrates of the ripe seeds of the legumes like those of the cereals consist very largely of starch with more or less fiber, and the heat of combustion is here taken as 4.2 calories per gram. The food materials consisting largely of starch, such as corn starch, tapioca, etc., may also be assumed to have a similar heat of combustion per gram of carbohydrates.

The heat of combustion of the glucoses averages not far from 3.75 and of sucrose 3.96 calories per gram. It is here assumed that the heat of combustion of cane sugar, and the sugars of sirup, molasses, etc., may be taken as 3.95 calories per gram.

The carbohydrates of vegetables such as potatoes, turnips, squash, etc., consist very largely of starch and cellulose with more or less sugars. The quantity of sugar in beets and parsnips is considerable, that in potatoes and turnips insignificant in amount. There is probably a larger proportion of pentosans in the carbohydrates of vegetables than in that of the cereals. The heat of combustion of the pentosans appears to be rather higher than that of the polyhexoses, and may perhaps offset the lower heat of combustion of the sugars. In lack of more definite data it is here assumed that the average heat of combustion of one gram of carbohydrates of vegetables is, like that of cereals and legumes, 4.2 calories per gram.

When we come to consider the carbohydrates of fruits, however, allowance must be made for the large proportion of sugars chiefly dextrose and levulose, the heats of combustion of which are considerably smaller than of the starches. There are at the same time certain amounts of starch, pentosans and cellulose, which tend to increase the heats of combustion of the mixed carbohydrates of fruits. In the light of these considerations it would seem that the average heat of combustion of the carbohydrates occurring in fruits might be not far from 4.0 calories per gram.

In the following table the heats of combustion of some of the principal kinds of carbohydrates and the values here assumed for the carbohydrates of different kinds of food materials are

tabulated. It is of course to be understood that these factors, like those for protein and fats, are simply tentative, based upon the best data we have been able to obtain.

TABLE 8.

Average determined heats of combustion of different carbohydrates and assumed factors for carbohydrates of different groups of food materials.

KIND OF MATERIAL.	HEAT OF COMBUSTION PER GRAM.	
	Determined.	Assumed or calculated.
	Calories.	Calories.
Pentoses,	3.72 to 4.38	—
Dextrose,	3.75	—
Levulose,	3.76	—
Cane sugar,	3.96	—
Milk sugar,	3.86	—
Cellulose,	4.20	—
Starch,	4.20	—
Dextrin,	4.11	—
Glycogen,	4.19	—
Carbohydrates of animal foods, meats, dairy products, etc.,	—	3.90
Carbohydrates of cereals,	—	4.20
Carbohydrates of legumes,	—	4.20
Sugars,	—	3.95
Starches,	—	4.20
Carbohydrates of vegetables,	—	4.20
Carbohydrates of fruits,	—	4.00

TESTS OF ACCURACY OF PROPOSED FACTORS FOR HEATS OF COMBUSTION.

The figures of Tables 6, 7, and 8, taken in connection with the percentage composition of any given food material, enable us to compute its heat of combustion. If the heat of combustion has been actually determined by the bomb calorimeter it gives a means of testing the accuracy of the factors thus assumed. Many analyses of food materials in which the heat of combustion was determined are available for this purpose. A large portion of these have been made in connection with the investigations upon the food and nutrition of man carried on under the auspices of the United States Department of Agriculture, in coöperation with this and other experiment stations and educational institutions. Table 9 shows the computed and determined heat of combustion in 276 samples of food materials, 220 of which were analyzed in this laboratory and the remainder by Prof. Grindley of the University of Illinois.

The number of analyses in this comparison might be largely increased, but it is believed that a sufficient number have been taken to show the agreement between the computed and determined values. The method of computing the heat of combustion of the different materials was as follows: In a sample of wheat bread, for example, the water-free substance contained 14.8 per cent. protein, 2.9 per cent. fat, and 80.2 per cent. carbohydrates, and had a heat of combustion, as actually determined, of 4.529 calories per gram. One gram of the water-free material contains, therefore, .148, .029, and .802 grams of protein, fats, and carbohydrates respectively, and its heat of combustion as computed from the factors given in Tables 6, 7, and 8 would be $(.149 \times 5.80 + .029 \times 9.30 + .802 \times 4.20 =)$ 4,502 calories per gram. All of the comparisons have been made on the basis of the water-free material.

TABLE 9.

Comparison of heats of combustion as calculated by use of the above factors with results found by actual experiment.

KIND OF FOOD MATERIAL.	Number of analyses included in average.	AVG. HEAT OF COMBUSTION PER GRAM OF WATER-FREE SUBSTANCE.		Calculated results in percentages of those determined.
		Determined.	Calculated.	
		Calories.	Calories.	%
Beef,	55	6507	6619	101.7
Beef, canned,	7	6197	6268	101.2
Mutton,	10	7146	7316	102.4
Pork,	10	7835	7944	101.4
Poultry,	5	6310	6508	103.1
Fish,	3	6317	6427	101.8
Eggs,	10	7103	7160	100.8
Butter,	20	8832	8918	101.0
Milk,	37	5437	5413	99.6
Breakfast foods,	3	4367	4360	99.8
Bread, crackers, etc.,	36	4536	4513	99.5
Corn (maize) meal and corn preparations,	7	4580	4624	101.0
Rye preparations,	6	4353	4343	99.8
Barley preparations,	2	4352	4365	100.3
Rice,	5	4390	4474	101.9
Oatmeal (rolled oats),	2	4834	4811	99.5
Oatmeal, cooked,	6	4488	4480	99.8
Wheat, pastry,	8	4579	4605	100.6
Legumes, fresh,	8	4367	4361	99.9
Legumes, cooked,	5	4312	4343	100.7
Vegetables, fresh,	10	4195	4051	96.6
Vegetables, cooked,	3	4057	4277	105.4
Vegetables, canned,	2	4264	4102	96.2
Fruits, fresh,	12	4389	4123	93.9
Fruits, canned,	4	4078	4056	99.5
Average 276 samples,	—	—	—	100.3

There were at times quite marked variations between the heats of combustion actually found and those calculated, amounting in some cases to as much as 5 or even 6 per cent. of the former value. On the whole, however, the agreement is as close as could well be expected when we consider the relatively small amount of data upon which some of the assumptions involved in deriving the factors are based, and when we consider, on the other hand, the possibility of errors in the chemical analyses. Indeed, it seems to us that the agreement in a large number of cases has been sufficiently close to warrant the use of these factors as a check on the analytical work or on the determinations of the actual heats of combustion by means of the bomb calorimeter. Thus if marked discrepancies occur in any given case between the calculated heats of combustion and those determined by the bomb calorimeter, either the analytical work may well be repeated or the heat of combustion redetermined or both. Of course in some prepared foods made up of several different kinds of food materials, pastries for example, which contain an unknown proportion of sugars and starches, the calculated heat of combustion may differ considerably from the computed, and cannot be used as giving any check upon the analytical results.

FUEL VALUE.

In accordance with the definitions in the previous article (see pages 69–72) the fuel value of a given food material is measured by the difference between its heat of combustion and the heats of combustion of the corresponding feces and urine. It is assumed that under normal conditions the fats and carbohydrates are completely oxidized in the body, and that hence their fuel values will be their total heats of combustion less those of the unavailable portions; in other words, the heats of combustion of the available portions. It is also assumed that all of the energy yielding material of the urine comes from the incomplete oxidation of the protein of the food. The heat of combustion of protein as determined with the bomb calorimeter measures the heat evolved in the complete oxidation of the carbon to carbon dioxide, and the hydrogen to water, while the nitrogen remains in the free state. In the body, however, oxidation of nitrogenous compounds cannot be carried as far and the

nitrogen is excreted in the form of urea, uric acid, and allied compounds. The carbon and hydrogen, however, appear to be oxidized completely to carbon dioxide and water with the exception of the small amounts in combination with the nitrogen in the urine. The urine also contains a small amount of non-nitrogenous organic material, part of which may not improbably be derived from the digested fats and carbohydrates of the food. It is customary, however, to consider the heat of combustion of the urine as representing that portion of the energy of the protein which is broken down which the body cannot utilize. In other words, we assume that the total potential energy of the available fats and carbohydrates is itself available for use in the body while only a portion, although the major portion, of the energy in the available protein is thus available.

This brings out the distinction between the availability of the material and of the energy belonging to it. In speaking of the available material we refer to the portion which is digested and absorbed less the corresponding metabolic products which are eliminated with the undigested residue, and are regarded as required for the process of digestion. The available energy of the fats and carbohydrates is the total energy of their available material. In the case of protein, however, the available material is not fully oxidized, and the available energy is the total less that of the material which escapes oxidation. The last statement requires qualification, because it does not distinguish between the proteids and non-proteids of the protein. To be strictly accurate we should have to consider the proteids themselves, determine their amounts, availability and heats of combustion, and also learn by some means how much of their energy is transformed in the body by oxidation and how much is left in the residues excreted in the urine. The different classes of non-proteids could be treated in like manner. Our present knowledge, however, does not permit such determinations, nor are the experimental methods by which they should be made as yet sufficiently elaborated.

The best we are able to do at present is to determine as nearly as practicable the proportions of protein which are actually available and the heat of combustion of the material in the urine which is assumed to come from the incomplete oxidation of the protein compounds.

We measure the protein by multiplying the nitrogen by a given factor which varies with different food materials. The factor for computing the total protein of a given diet is decided by the proportions of the different food materials and their several nitrogen factors. We assume that the nitrogen factor is the same for the available protein as for the corresponding total protein. It may be that later inquiry will show that this assumption is incorrect, but in lack of more accurate knowledge we can do no better than follow the present plan.

The heat of combustion of the water-free substance of the urine is determined by the usual method of oxidation by means of the bomb calorimeter and can be compared with the corresponding nitrogen of the urine, thus showing the ratio of nitrogen to the heat of combustion. A similar ratio of nitrogen to heat of combustion of protein could be established if necessary.

A considerable amount of experimental data has accumulated in this laboratory within the past few years concerning this ratio of nitrogen to energy in the urine. A few like determinations* have been made by Prof. Chas. D. Woods, formerly of this Station and now Director of the Maine Experiment Station. As the average of forty-six determinations of this ratio it was found that for every gram of nitrogen in the urine there was unoxidized material sufficient to yield 7.9 calories of energy. On the assumption already made that all the energy in the urine is derived from incompletely oxidized available protein, we may substitute for the ratio of nitrogen to energy the ratio of available protein to energy. This value is found in the following manner: One gram of nitrogen in the urine is assumed to represent the breaking down or catabolism of 6.25 grams of available protein of food or of body protein. This assumption is slightly inaccurate owing to the presence in the food of some proteids, such as those of wheat and rye, and more especially the non-proteids containing more than 16 per cent. of nitrogen. It does, however, come close to the truth. For every 6.25 grams of protein consumed, therefore, there would be 7.9 calories of energy in the unoxidized materials of the urine, or about 1.25 calories per gram ($7.9 \div 6.25 = 1.26$).

* Unpublished.

Using the figures for availability and heat of combustion of protein compounds given in Table 4 (page 86) and Table 6 (page 92), and the factor 1.25 as expressing the amount of energy lost in the urine per gram of available protein, the calculation of the fuel value of protein is simple. We may take for instance the protein of meat. This is assumed to have a heat of combustion of 5.65 calories per gram. Ninety-seven per cent. of this protein is rendered available for use in the body; the total energy of the available protein corresponding to 1 gram of total protein would be 5.5 calories ($5.65 \times .97 = 5.48$). Of this 5.5 calories, however, 1.25 calories will be contained in the incompletely oxidized material of the urine, so that the actual amount of energy obtained by the body from the gram of protein eaten is equal to 4.25 calories ($5.65 \times .97 - 1.25 = 4.23$). In other words, on the basis of the previous assumption the fuel value of 1 gram of protein of meat is 4.25 calories per gram. In a similar manner we may calculate the fuel value of 1 gram of protein of cereals. The heat of combustion per gram is approximately 5.8 calories, and 85 per cent. of the protein appears to be available for use in the body. But for every gram of protein thus available not far from 1.25 calories of energy is lost in the urine. The fuel value, therefore, of 1 gram of protein of cereals as thus computed is 3.7 calories ($5.80 \times .85 - 1.25 = 3.68$). Similar computations give factors for fuel value of protein of eggs, dairy products, legumes, vegetables and fruits. The results of these calculations are shown in Table 10 beyond.

In determining factors for fuel value of fats and carbohydrates we have to consider only the total energy and the proportion actually available, since we assume that none of the energy of these nutrients is lost in the urine. It appears, for example, that 95 per cent. of the fat of meat is utilized within the body. The average heat of combustion of 1 gram of meat fat is 9.5 calories, and the energy of the available material, which for fats is the same as its fuel value, would therefore be 9 calories per gram ($9.5 \times .95 = 9.02$). In a similar manner the fuel value of the carbohydrates is found by deducting the energy in the unavailable portion from the total energy. The heat of combustion of 1 gram of carbohydrates of cereals, for example,

is 4.2 calories, and 98 per cent. is available. Accordingly the factor for 1 gram would be 4.1 calories ($4.2 \times .98 = 4.12$).

In Table 10 beyond are summarized the factors for fuel value of nutrients in different groups of food materials, together with factors for heats of combustion, availability, etc. The method of deriving the quantities in the different columns is in part indicated by algebraic expressions in the column headings. The quantities in column A represent in round numbers the approximate proportion of the different nutrients found in each of the different groups of food materials in the average diet as based upon the results obtained in an examination of 185 actual dietary studies. The figures are essentially the same as those given in Table 3 above. The figures in column B are taken from Tables 6, 7 and 8 above, and represent the factors for the heat of combustion or total energy per gram of the nutrients in the different groups of food materials. In computing the figures for the heats of combustion of total animal food, total vegetable food, and total food in the average mixed diet, account is taken of the proportional amounts of the nutrients furnished by the different groups of food materials as shown in column A and the heat of combustion of these nutrients as shown in column B. For example, in the ordinary mixed diet about 43 grams out of every 100 of protein is furnished by meat, fish, etc. This 43 grams, with a heat of combustion of 5.65 calories per gram, supplies a total energy of 243.0 calories ($43 \times 5.65 = 243$). In the same diet 6 grams of protein would come from eggs. This, at 5.75 calories per gram, furnishes 34.5 calories. The dairy products furnish 12 grams of protein, with a heat of combustion of 5.65 calories per gram, making 67.8 calories. The total animal food thus supplies ($43 + 6 + 12 =$) 61 grams of the 100 grams of the whole diet, and these 61 grams of animal protein contain a total of ($243 + 34.5 + 67.8 =$) 345.3 calories, which are equal to ($345.3 \div 61 = 5.651$) 5.65 calories per gram. In like manner the 39 grams of vegetable protein are made up of 31 grams of protein from cereals with a heat of combustion of 5.80 calories per gram; 2 grams from legumes with a heat of combustion of 5.70; 5.5 grams from vegetables with a heat of combustion of 5.00; and .5 of a gram from fruit with a heat of combustion of 5.20 calories per gram. We thus have 421.3 calories

furnished by the 39 grams of vegetable protein, or 5.65 calories per gram. Both the animal and the vegetable protein average approximately 5.65 calories per gram, which is therefore the average heat of combustion of the total protein of the diet.

In a similar manner we may compute the average heat of combustion of the fats and carbohydrates in mixed diet. Out of every 100 grams of total carbohydrates 95 are obtained from the vegetable food materials, with a total heat of combustion of 392.8 calories. The heat of combustion per gram therefore amounts to ($392.8 \div 95 =$) 4.135 calories, or approximately 4.15 calories per gram. The animal carbohydrates with a heat of combustion of 3.90 calories per gram furnish ($3.90 \times 5 =$) 19.5 calories of energy, making the total heat of combustion of 100 grams of carbohydrates in mixed diet ($392.8 + 19.5 =$) 412.3 calories, or approximately 4.15 calories per gram.

The factors for total animal food, total vegetable food and total food in the remaining columns of Table 10 are obtained in a manner similar to that just described.

In what has been said regarding the available energy of the different nutrients in different classes of food materials reference was made to the fuel value per gram of total protein, fats, or carbohydrates. The figures in the last column of Table 10 give the factors representing these fuel values. It may frequently occur, however, that corresponding factors are needed for the fuel value of one gram of available protein, fats, or carbohydrates. The potential energy of one gram of available protein is assumed to be the same as that of one gram of total protein. In other words, it is assumed that the energy of one gram of available is the same as that of one gram of unavailable protein. While this may not be strictly true, there is little or no experimental evidence warranting any other supposition. It follows, therefore, that the fuel value of one gram of available protein is its heat of combustion less 1.25 calories —the energy lost in the urine. If, as has been assumed, none of the potential energy of its available fats and carbohydrates is lost in the organic matter of the urine, then the fuel value of one gram of available fats or carbohydrates will be the same as its heat of combustion, or as the heat of combustion of one gram of corresponding material of total food. These factors

for fuel value per gram of available nutrients are given in the next to the last column of Table 10.

TABLE 10.

Factors for heats of combustion and fuel values of nutrients in different groups of food materials and in mixed diet.

KIND OF FOOD MATERIAL.	Nutrients furnished by each group per 100 grams total.	Heat of combustion per gram.	Proportion of total nutrients actually available.	Total energy per gram in available nutrients.	FUEL VALUE. Per gram available nutrients.	FUEL VALUE. Per gram total nutrients.
	A	B	C	D =B X C	E*	F†
Protein.	Grams.	Cal.	%	Cal.	Cal.	Cal.
Meats, fish, etc.,	43.0	5.65	.97	5.50	4.40	4.25
Eggs,	6.0	5.75	.97	5.60	4.50	4.35
Dairy products,	12.0	5.65	.97	5.50	4.40	4.25
Animal food,	61.0	5.65	.97	5.50	4.40	4.25
Cereals,	31.0	5.80	.85	4.95	4.55	3.70
Legumes,	2.0	5.70	.78	4.45	4.45	3.20
Vegetables,	5.5	5.00	.83	4.15	3.75	2.90
Fruits,	0.5	5.20	.85	4.40	3.95	3.15
Vegetable food,	39.0	5.65	.85	4.80	4.40	3.55
Total food,	100.0	5.65	.92	5.20	4.40	4.00
Fat.						
Meat and eggs,	60.0	9.50	.95	9.00	9.50	9.00
Dairy products,	32.0	9.25	.95	8.80	9.25	8.80
Animal food,	92.0	9.40	.95	8.95	9.40	8.95
Vegetable food,	8.0	9.30	.90	8.35	9.30	8.35
Total food,	100.0	9.40	.95	8.90	9.40	8.90
Carbohydrates.						
Animal food,	5.0	3.90	.98	3.80	3.90	3.80
Cereals,	55.0	4.20	.98	4.10	4.20	4.10
Legumes,	1.0	4.20	.97	4.05	4.20	4.05
Vegetables,	13.0	4.20	.95	4.00	4.20	4.00
Fruits,	5.0	4.00	.90	3.60	4.00	3.60
Sugars,	21.0	3.95	.98	3.85	3.95	3.85
Vegetable food,	95.0	4.15	.97	4.00	4.15	4.00
Total food,	100.0	4.15	.97	4.00	4.15	4.00

* Values for fats and carbohydrates, same as corresponding values in column B. Values for protein, same as corresponding values in column B minus 1.25.

† Values for fats and carbohydrates, same as corresponding values in column D. Values for protein, same as corresponding values in column D minus 1.25.

The factors for fuel value in Table 10 represent the available energy per gram. Corresponding values per pound can be readily computed by multiplying the values per gram by 453.6, the number of grams in a pound. In the ordinary mixed diet the fuel value of one pound of protein as thus computed from the figures of Table 10 is 1,820, of fat 4,040, and of carbohydrates 1,820 calories. The corresponding values per pound of available nutrients are 2,000, 4,260, and 1,860 calories respectively.

APPLICATION OF PROPOSED FACTORS FOR FUEL VALUE TO ACTUAL DIGESTION EXPERIMENTS.

In the preceding pages the factors for availability and for heats of combustion have been applied to experimental data in such a way as to test their accuracy. In a similar manner the reliability of the proposed factors for fuel value may be tested by applying them to the quantities of nutrients consumed in digestion experiments with mixed diet of more or less simple character, and comparing the computed fuel value of the diet with that actually found by experiment, *i. e.*, the difference between the total energy of the food and that of the feces and urine.

The results of a considerable number of digestion experiments are available for the purpose of such comparison. Thus far we have made the necessary calculations from the data of twenty-seven experiments carried on in this laboratory in connection with investigations with the respiration calorimeter.* In some of these the subject was outside the respiration apparatus, the study being preliminary to the more detailed experiments within the respiration chamber. These are indicated in Table 11 beyond as "ordinary" experiments. In other experiments the subject was in the apparatus. These are indicated as "respiration" experiments. Each "ordinary" experiment was immediately followed by one or more "respiration" experiments with the same man. The kinds and amounts of food in the "ordinary" or preliminary experiments were very nearly the same as in the subsequent "respiration" experiments.

* The details of the digestion experiments are to be published in a Bulletin of the Office of Experiment Stations of the U. S. Department of Agriculture.

The data of these digestion experiments serve for making a comparison not only of the fuel values as computed and as actually found by experiment, but also of the total energy as computed and as actually determined. In making these computations the quantities of protein, fats, and carbohydrates furnished by the different nutrients consumed were multiplied by the corresponding factors for heats of combustion and for fuel values, and thus the total computed energy and fuel value of the diet was found. The proportion which the calculated values bear to the corresponding values as actually determined was then computed. Thus in digestion experiment No. 37, 1,165 grams of meat were consumed, furnishing 326 grams of protein and 69 grams of fat. The heat of combustion of the protein of meat was assumed to be 5.65 calories per gram and of fat 9.5 calories per gram. The heat of combustion as calculated thus amounts to 2,497 calories ($326 \times 5.65 + 69 \times 9.5 = 2,497$). The fuel value of the 326 grams of protein and 69 grams of fat was found by multiplying by the factors 4.25 and 9.00 respectively, and amounts to 2,007 calories ($326 \times 4.25 + 69 \times 9.0 = 2,007$). In a similar manner the heat of combustion and fuel value of the other foods used were calculated. The total heat of combustion of the diet as calculated amounted to 21,763 calories, while the actual determination by means of the bomb calorimeter showed 21,467 calories. The calculated value was thus 101.4 per cent. of that actually determined. The fuel value of the diet as calculated amounted to 19,559 calories, while the amount of energy actually made available in this experiment was 19,299 calories. The calculated fuel value was thus 101.4 per cent. of the fuel value actually found by experiment.

The results of these comparisons are shown in Table 11 on the following page. It is of considerable interest to note that in the twenty-seven experiments compared in this table the maximum variation between the heat of combustion as calculated and as found amounts to but 2.5 per cent. of the latter value, while the average values are identical. At the same time the fuel value as calculated ranges from 3.1 per cent. above to 2.1 per cent. below that actually found by experiment, the average difference in twenty-seven experiments being but one part in a thousand. This close agreement between the computed values

and those actually found by experiment may of course be due to compensation of errors, and when a large number of experiments are compared in the same way the results may prove less strikingly concordant, but it seems hardly probable that the proposed factors for heats of combustion and fuel value can be very far out of the way.

TABLE II.

Comparison of heats of combustion and fuel values of nutrients of food consumed in digestion experiments as calculated by use of the proposed factors and as found by experiment.

No. of experiment.	CHARACTER OF EXPERIMENT.*	Heats of combustion calculated in per cent. of that actually found.	Fuel value calculated in per cent. of that actually found.	No. of experiment.	CHARACTER OF EXPERIMENT.*	Heats of combustion calculated in per cent. of that actually found.	Fuel value calculated in per cent. of that actually found.
		%	%			%	%
37	Ordinary, -	101.4	101.4	51	Ordinary, -	100.4	101.4
38	Respiration, -	101.2	101.8	52	Respiration, -	99.9	99.3
39	Ordinary, -	99.3	98.1	76	Ordinary, -	100.7	98.8
40	Respiration, -	99.4	97.9	77	Respiration, -	99.9	100.3
41	Ordinary, -	102.1	103.1	78	Ordinary, -	99.1	99.2
42	Respiration, -	102.5	100.2	79	Respiration, -	99.4	98.9
43	Ordinary, -	99.7	100.3	80	Ordinary, -	98.9	99.4
44	Respiration, -	99.8	99.0	81	Respiration, -	98.7	98.9
45	Ordinary, -	100.2	103.1	82	Ordinary, -	99.3	99.0
46	Respiration, -	100.2	101.7	83	Respiration, -	99.4	99.2
47	Ordinary, -	100.7	100.7	84	Ordinary, -	98.5	98.3
48	Respiration, -	100.6	102.0	85a	Respiration, -	98.7	98.6
49	Ordinary, -	101.0	101.8	85b	Respiration, -	98.6	98.9
50	Respiration, -	101.0	102.4		Avg. 27 expts .	**100.0**	**100.1**

* These twenty-seven experiments were made in connection with investigations with the respiration calorimeter. Those marked "ordinary" were conducted outside the apparatus, and immediately preceded the respective "respiration" experiments in which the subject was inside the respiration chamber.

COMPARISON OF FACTORS HERE PROPOSED WITH THOSE PROPOSED BY RUBNER.

The factors for fuel value now in most common use are those proposed by Rubner,† in 1885. This investigator assigns 4.1 calories per gram to the protein, 9.3 to the fats, and 4.1 to the carbohydrates of ordinary mixed diet.

† Ztschr. Biol., 21 (1885), p. 377.

In the estimates upon which these figures are based Rubner made use of the heats of combustion of the compounds of the different classes of nutrients in so far as they were available at the time. For the potential energy of the material excreted in the urine he used the results of determinations of the nitrogen and heats of combustion of the water-free substance of the urine of dogs with a diet of meat. He assumed that 60 per cent. of the protein of ordinary mixed diet was of animal and 40 per cent. of vegetable origin. He made allowance for the energy in the feces as determined by experiments with dogs on a meat diet, but made no allowance for any undigested residue of the fats and carbohydrates of the food. To state the case in another way, he assumed the fuel value ("Wärmewerth") of the fats and carbohydrates to be the same as their heats of combustion, but estimated the similar factors for the protein by subtracting the heat of combustion of feces and urine from the total heat of combustion of the protein of the food. Considering the paucity of his data and the fact that he made no allowance for either the undigested material or the metabolic products of the feces properly belonging to the carbohydrates and fats, the results are certainly very close to those to which we are led by the use of the more extensive data now available. The closeness of this agreement appears to be partially due to a balancing of errors. The heats of combustion which Rubner used were largely those determined by means of the Thompson-Stohmann calorimeter, which gave rather too low results. We hope to discuss this subject more fully in a later article.

SUMMARY.

The object of the preceding discussion is to deduce factors for estimating the nutritive values of materials used for the food of man.

The principal data used for these estimations are the percentages, coefficients of availability, heats of combustion, and fuel values of the protein, fats, and carbohydrates in food materials and the proportional amounts of different kinds of foods used in the average diet. The proportions of nutrients in ordinary food are found by analysis. There are now available analyses of not

far from 4,000 specimens of American food materials. In estimating the proportion of nutrients in ordinary mixed diet, the results of 185 studies of actual dietaries were employed. These studies have been made in different parts of the United States, mostly within the past ten years; some by persons connected with this Station, but the larger number by other investigators engaged in the coöperative inquiry under the auspices of the U. S. Department of Agriculture, of which the work here reported may be said to form a part. The coefficients of availability are based largely upon the results of digestion experiments with men. These belong to the coöperative inquiry just referred to, and a considerable number were made by this Station. The data for heats of combustion have been compiled from various sources, and included results obtained in this laboratory. The factor for the heat of combustion of the unoxidized material of the urine is based upon the results of the examination of 46 specimens of urine of healthy men with mixed diet. These results were mostly obtained in this laboratory in connection with digestion and metabolism experiments.*

The outcome of these estimates may be stated as follows:

Taking into account (1) the heats of combustion of the protein compounds, fats and carbohydrates which occur in different groups of food materials, and (2) the average proportion in which the different nutrients are furnished by different food materials in the ordinary mixed diet, the average heat of combustion of one gram of protein, fat and carbohydrates in such diet is approximately 5.65, 9.40 and 4.10 calories respectively.

The results of a considerable number of digestion experiments with mixed diet give averages for coefficients of availability as follows: For protein 92 per cent., fats 95 per cent., and carbohydrates 97 per cent.

One gram of total protein of mixed diet burned in the body yields on the average not far from 4.0 calories, one gram of fat 8.9 calories, and one gram of carbohydrates 4.0 calories of energy. The corresponding values per pound are 1,820, 4,240 and 1,820 calories. One gram of available protein on the other hand has a fuel value of 4.4 calories, one gram of available fats 9.4 calories, and one gram of available carbohydrates 4.1 calories. These values correspond to 2,000, 4,260 and 1,860 calories per gram.

* See second foot-note on p. 111.

The following table summarizes the various factors for nutrients of mixed diet:

TABLE 12.

Factors for heats of combustion, availability and fuel values of nutrients in mixed diet.

Kind of Material.	Heat of combustion per gram.	Availability.	Fuel Value. Referred to available nutrients. Per gram.	Referred to available nutrients. Per lb.	Referred to total nutrients. Per gram.	Referred to total nutrients. Per lb.
	Cal.	%	Cal.	Cal.	Cal.	Cal.
Protein,	5.65	92	4.4	2000	4.0	1820
Fats,	9.40	95	9.4	4260	8.9	4040
Carbohydrates,	4.10	97	4.1	1860	4.0	1820

Of course these figures are not to be regarded as final, and alterations may be called for as data accumulate. Meanwhile we think that they are sufficiently accurate for ordinary use.

COMPOSITION OF COMMON FOOD MATERIALS—AVAILABLE NUTRIENTS AND FUEL VALUE.

BY W. O. ATWATER AND A. P. BRYANT.

Previous reports of this Station have contained tables of average composition of food materials. In these tables, with one exception,* no attempt was made to show the actual amounts and fuel values of the nutrients which are available for use in the body. These may, however, be computed by use of the data given and the conclusions reached in the preceding article. Thus, by the application of the factors for availability given in Table 12, on page 110, we may compute the actual proportions of available and unavailable nutrients in different food materials, and by means of the factors given in the same table for the fuel value of protein, fats, and carbohydrates in different groups of food materials, we may compute the actual amounts of energy which they yield to the body.

In the following table the figures for percentage composition of the different food materials were taken from a compilation made by the writers of over 4,000 analyses of American food materials, of which nearly 1,000 were made in this laboratory.† The table shows the proportions of available nutrients, and the available energy per pound in each of a considerable number of food materials, as computed from the data mentioned above. In such food materials as contain refuse the composition of the material both with and without refuse is given. Take for example beef brisket. The edible portion (e. p.) of this contains, as the average of the analyses now accessible, 54.6 per cent. of water, 15.8 per cent. protein (N. × 6.25), 28.5 per cent. fat, and .9 per cent. mineral matter or ash.

* Report of Storrs Experiment Station, 1896, p. 202.

† See U. S. Department of Agriculture, Office of Experiment Stations, Bulletin 28, Revised, The Chemical Composition of American Food Materials. By W. O. Atwater and A. P. Bryant.

Taking 97 per cent. of the protein, 95 per cent. of the fat, and 75* per cent. of the ash as available for use in the body (see Table 4) the composition of beef brisket may be given as follows: Water, 54.6 per cent.; unavailable nutrients, 2.1 per cent.; available protein, 15.3 per cent. (15.8 × .97); available fat, 27.1 (28.5 × .95); and available mineral matter, .7 per cent. (.9 × .75). The fuel value of one pound of this meat would then be calculated by use of the factors given in Table 10, page 104. In one gram of the material there is actually available to the body .153 grams of protein, the fuel value of which is (.153 × 4.4 =) .673 calories, and .271 gram of fat with a fuel value of (.271 × 9.5 =) 2.575 calories, making a total fuel value of 3.248 calories per gram. To obtain the corresponding value per pound we multiply the value per gram by the number of grams in one pound (453.6). The fuel value of one pound of the brisket is therefore (3.248 × 453.6 = 1,473) 1,475 calories.

Unless otherwise stated the figures in the following table apply to materials of average composition. There are at times wide variations in the proportion of fat in meat from the same cut, *e. g.*, beef round. Indeed, the leaner cuts from a fat animal may be as fat as the fatter cuts from a lean animal. This variation in the composition of similar portions of a lean, medium fat and fat animal is illustrated by a few examples in the following table.

When the material as ordinarily found in the market contains refuse such as bone, tendon, shell, skin, seeds, etc., the composition of both the edible material and of the material as purchased is usually given. The former is designated by the letters e. p., the latter by the letters a. p. In such food materials as ordinarily contain no refuse the composition of the edible material is identical with that of the material as purchased, and the letters e. p. and a. p. are omitted in the table.

* In lack of satisfactory data, it is here assumed that 75 per cent. of the mineral matters of different food materials is available.

TABLE 13.

Composition of ordinary food materials.

a. p. = as purchased. e. p. = edible portion. See page 112.

KIND OF FOOD MATERIAL.		Refuse.	Water.	Unavailable nutrients.	AVAILABLE NUTRIENTS. Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel value per lb.
ANIMAL FOODS. *Beef (fresh).*		%	%	%	%	%	%	%	Calories.
Brisket,	e. p.,	—	54.6	2.1	15.3	27.1	—	.7	1475
	a. p.,	23.3	41.6	1.6	11.6	21.2	—	.5	1145
Chuck,	e. p.,	—	62.7	1.8	17.9	17.1	—	.7	1095
	a. p.,	16.3	52.6	1.4	15.0	14.3	—	.6	915
Flank,	e. p.,	—	60.2	1.9	18.3	19.9	—	.7	1225
	a. p.,	10.2	54.0	1.7	16.5	18.0	—	.5	1105
Loin, lean,	e. p.,	—	67.0	1.2	19.1	12.1	—	1.0	900
	a. p.,	13.1	58.2	1.1	16.6	10.5	—	.9	785
Loin, medium,	e. p.,	—	60.6	1.8	17.9	19.2	—	.8	1185
	a. p.,	13.3	52.5	1.6	15.6	16.6	—	.7	1025
Loin, fat,	e. p.,	—	54.7	1.9	17.0	26.2	—	.9	1470
	a. p.,	10.2	49.2	1.8	15.2	23.6	—	.8	1320
Neck,	e. p.,	—	63.4	1.6	19.5	15.7	—	.7	1065
	a. p.,	27.6	45.9	1.2	14.1	11.3	—	.5	770
Plate,	e. p.,	—	54.4	2.2	16.0	27.6	—	.6	1510
	a. p.,	16.5	45.3	1.8	13.4	23.2	—	.5	1265
Ribs,	e. p.,	—	55.5	2.0	17.0	25.3	—	.7	1430
	a. p.,	20.8	43.8	1.8	13.5	20.0	—	.5	1130
Round, lean,	e. p.,	—	70.0	1.0	20.7	7.5	—	1.1	735
	a. p.,	8.1	64.4	1.0	18.9	6.9	—	1.0	675
Round, medium,	e. p.,	—	65.5	1.6	19.7	12.9	—	.8	950
	a. p.,	7.2	60.7	1.4	18.4	12.2	—	.8	895
Round, fat,	e. p.,	—	60.4	1.6	18.9	18.5	—	1.0	1175
	a. p.,	12.0	54.0	1.3	17.0	15.3	—	.8	1000
Round, second cut,	e. p.,	—	69.8	1.3	19.8	8.2	—	.8	750
	a. p.,	19.5	56.2	1.0	15.9	6.6	—	.7	600
Rump,	e. p.,	—	56.7	2.0	16.9	24.2	—	.7	1380
	a. p.,	20.7	45.0	1.6	13.4	19.2	—	.5	1095
Fore shank,	e. p.,	—	67.9	1.4	19.8	11.0	—	.7	865
	a. p.,	36.9	42.9	.9	12.4	6.9	—	.5	545
Hind shank,	e. p.,	—	67.8	1.4	20.3	10.9	—	.7	875
	a. p.,	53.9	31.3	.7	9.3	5.0	—	.3	400
Shoulder and clod,	e. p.,	—	68.3	1.5	19.0	10.7	—	.8	840
	a. p.,	16.4	56.8	1.2	15.9	9.3	—	.7	720
Fore quarter,	e. p.,	—	60.4	1.8	17.4	20.3	—	.7	1220
	a. p.,	18.7	49.1	1.5	14.1	16.6	—	.5	995
Hind quarter,	e. p.,	—	59.8	1.8	17.8	20.5	—	.7	1240
	a. p.,	15.7	50.4	1.6	14.9	17.4	—	.5	1045
Side, lean,	e. p.,	—	67.2	1.3	18.7	12.5	—	.9	910
	a. p.,	19.5	54.1	1.0	15.0	10.1	—	.7	735
Side, medium,	e. p.,	—	59.7	1.8	17.6	20.9	—	.7	1250
	a. p.,	17.4	49.4	1.5	14.4	17.2	—	.5	1030
Side, fat,	e. p.,	—	47.8	2.5	15.7	34.6	—	.5	1805
	a. p.,	13.2	41.5	2.1	13.6	30.0	—	.5	1565
Liver,	e. p.,	—	71.2	1.2	20.4	4.3	1.7	1.2	620
	a. p.,	7.0	66.2	1.2	18.9	4.0	1.6	1.1	580

TABLE 13.—*(Continued.)*

a. p. = as purchased. e. p. = edible portion. See page 112.

Kind of Food Material.		Refuse.	Water.	Unavailable nutrients.	Available Nutrients. Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel value per lb.
ANIMAL FOODS. *Beef (fresh).*		%	%	%	%	%	%	%	Calories.
Suet (unrendered tallow),	a. p.,	—	13.7	4.3	4.6	77.7	—	.2	3440
Tongue,	e. p.,	—	70.8	1.3	18.3	8.7	—	.8	740
	a. p.,	26.5	51.8	.9	13.7	6.4	—	.6	550
Beef (preserved and cooked).									
Dried and smoked,	e. p.,	—	54.3	3.5	29.1	6.2	—	6.8	850
	a. p.,	4.7	53.7	4.5	25.6	6.6	—	5.5	795
Brisket, corned,	e. p.,	—	50.9	3.2	17.8	23.5	—	4.2	1370
	a. p.,	21.4	40.0	2.5	14.0	18.4	—	3.4	1070
Flank, corned,	e. p.,	—	49.9	2.7	14.2	31.4	—	2.2	1635
	a. p.,	12.1	43.7	2.5	12.5	27.7	—	2.0	1445
Plate, corned,	e. p.,	—	40.1	3.7	13.3	39.8	—	3.5	1980
	a. p.,	14.5	34.3	3.2	11.3	34.0	—	3.0	1690
Rump, corned,	e. p.,	—	58.1	2.2	14.8	22.1	—	2.8	1250
	a. p.,	6.0	54.5	2.3	13.9	20.9	—	2.3	1180
Canned, boiled,	a. p.,	—	51.8	2.2	24.7	21.4	—	1.0	1415
Canned, corned,	a. p.,	—	51.8	2.7	25.5	17.8	—	3.0	1275
Boiled beef (cut not given),	e. p.,	—	38.1	2.7	25.4	33.2	—	.7	1930
Roast, cooked,	e. p.,	—	48.2	2.4	21.6	27.2	—	1.0	1410
Loin steak, cooked,	e. p.,	—	54.8	2.0	22.8	19.4	—	.9	1290
Tripe, pickled,	a. p.,	—	86.5	.6	11.3	1.1	—	.2	275
Veal (fresh).									
Breast,	e. p.,	—	66.0	1.5	18.9	13.3	—	.8	950
	a. p.,	21.3	52.0	1.2	14.9	10.5	—	.6	750
Chuck,	e. p.,	—	73.0	1.1	19.1	6.2	—	.8	650
	a. p.,	18.9	59.5	1.0	15.5	4.9	—	.6	520
Cutlets (round),	e. p.,	—	70.7	1.3	19.7	7.3	—	.8	710
	a. p.,	3.4	68.3	1.2	19.5	7.1	—	.8	695
Flank,	a. p.,	—	68.9	1.3	19.9	9.9	—	.8	825
Leg,	e. p.,	—	70.0	1.3	19.6	8.6	—	.9	760
	a. p.,	14.2	60.1	1.1	15.0	7.5	—	.7	620
Loin,	e. p.,	—	69.0	1.3	19.3	10.3	—	.8	830
	a. p.,	16.5	57.6	1.1	16.1	8.6	—	.7	690
Neck,	e. p.,	—	72.6	1.1	19.7	6.6	—	.8	680
	a. p.,	31.5	49.9	.8	13.5	4.4	—	.5	460
Rib,	e. p.,	—	72.7	1.2	20.1	5.8	—	.8	650
	a. p.,	24.3	46.2	1.3	13.8	13.8	—	.6	870
Shank,	e. p.,	—	74.5	1.0	20.1	4.4	—	.8	590
	a. p.,	62.7	27.8	.4	7.5	1.6	—	.3	220
Fore quarter,	e. p.,	—	71.7	1.2	19.4	7.6	—	.7	715
	a. p.,	24.5	54.2	1.0	14.6	5.7	—	.5	535

TABLE 13.—*(Continued.)*

a. p. = as purchased. e. p. = edible portion. See page 112.

KIND OF FOOD MATERIAL.		Refuse.	Water.	Unavailable nutrients.	AVAILABLE NUTRIENTS. Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel value per lb.
ANIMAL FOODS.		%	%	%	%	%	%	%	Calories.
Veal (fresh).									
Hind quarter,	e. p.,	—	70.9	1.2	20.1	7.9	—	.8	740
	a. p.,	20.7	56.2	1.0	15.7	6.3	—	.6	585
Side,	e. p.,	—	71.3	1.2	19.6	7.7	—	.8	725
	a. p.,	22.6	55.2	1.0	15.1	6.0	—	.6	560
Liver,	a. p.,	—	73.0	.9	9.7	5.0	—	1.0	410
Lamb (fresh).									
Breast or chuck,	e. p.,	—	56.2	2.0	18.5	22.4	—	.8	1335
	a. p.,	19.1	45.5	1.7	14.9	18.1	—	.6	1075
Leg,	e. p.,	—	63.9	1.7	18.6	15.7	—	.8	1050
	a. p.,	17.4	52.9	1.4	15.4	12.9	—	.7	865
Loin,	e. p.,	—	53.1	2.2	18.1	26.9	—	.8	1520
	a. p.,	14.8	45.3	1.9	15.5	22.9	—	.6	1295
Neck,	e. p.,	—	56.7	1.9	17.2	23.6	—	.8	1360
	a. p.,	17.7	46.7	1.6	14.2	19.4	—	.6	1120
Shoulder,	e. p.,	—	51.8	2.2	17.6	28.2	—	.8	1565
	a. p.,	20.3	41.3	1.8	14.0	22.4	—	.6	1245
Fore quarter,	e. p.,	—	55.1	2.0	17.8	24.5	—	.8	1410
	a. p.,	18.8	44.7	1.7	14.5	19.9	—	.6	1145
Hind quarter,	e. p.,	—	60.9	1.8	19.0	18.1	—	.8	1160
	a. p.,	15.7	51.3	1.5	16.0	15.3	—	.7	980
Side,	e. p.,	—	58.2	2.0	17.1	21.9	—	.8	1285
	a. p.,	19.3	47.0	1.5	13.7	17.8	—	.6	1040
Lamb (cooked).									
Chops, boiled,	e. p.,	—	47.6	2.5	21.0	28.4	—	1.0	1640
	a. p.,	13.5	40.1	2.2	17.8	25.4	—	.9	1445
Leg, roast,	e. p.,	—	67.1	1.4	19.1	12.1	—	.6	905
Mutton (fresh).									
Chuck,	e. p.,	—	50.9	2.4	14.6	31.9	—	.7	1665
	a. p.,	21.3	39.9	1.8	11.5	25.4	—	.5	1325
Flank,	e. p.,	—	46.2	2.6	14.7	36.4	—	.5	1860
	a. p.,	9.9	39.0	2.3	13.4	35.1	—	.5	1780
Leg,	e. p.,	—	62.8	1.7	17.9	17.1	—	.8	1095
	a. p.,	18.4	51.2	1.4	14.6	14.0	—	.6	895
Loin,	e. p.,	—	50.2	2.4	15.5	31.4	—	.6	1660
	a. p.,	16.0	42.0	2.0	13.1	26.9	—	.5	1420
Neck,	e. p.,	—	58.1	2.0	16.4	23.4	—	.7	1335
	a. p.,	27.4	42.1	1.5	11.9	17.0	—	.5	970
Shoulder,	e. p.,	—	61.9	1.7	17.2	18.9	—	.7	1160
	a. p.,	22.5	47.9	1.4	13.3	14.7	—	.5	900
Fore quarter,	e. p.,	—	52.9	2.2	15.1	29.4	—	.7	1570
	a. p.,	21.2	41.6	1.8	11.9	23.3	—	.5	1240
Hind quarter,	e. p.,	—	54.8	2.1	16.2	26.7	—	.6	1475
	a. p.,	17.2	45.4	1.8	13.4	22.0	—	.5	1215
Side,	e. p.,	—	54.2	2.1	15.8	27.5	—	.7	1500
	a. p.,	18.1	45.4	1.8	12.6	21.9	—	.5	1195

TABLE 13.—*(Continued.)*

a. p. = as purchased. e. p. = edible portion. See page 112.

KIND OF FOOD MATERIAL.		Refuse.	Water.	Unavailable nutrients.	AVAILABLE NUTRIENTS.				
					Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel value per lb.
ANIMAL FOODS.		%	%	%	%	%	%	%	Calories.
Mutton (cooked and canned).									
Leg, roast,	e. p.,	—	50.9	2.1	24.3	21.5	—	.9	1410
Corned, canned,	a. p.,	—	45.8	3.0	27.9	21.7	—	3.2	1490
Tongue, canned,	a. p.,	—	47.6	3.1	23.7	22.8	—	3.6	1455
Pork (fresh).									
Chuck, ribs and shoulder,	e. p.,	—	51.1	2.3	16.8	29.5	—	.7	1605
	a. p.,	18.1	41.8	1.9	13.7	24.2	—	.6	1315
Flank,	e. p.,	—	59.0	1.9	17.9	21.1	—	.8	1265
	a. p.,	18.0	48.5	1.6	14.6	17.7	—	.5	1055
Loin, chops,	e. p.,	—	52.0	2.2	16.1	28.6	—	.8	1555
	a. p.,	19.7	41.8	1.8	13.0	23.0	—	.6	1250
Ham,	e. p.,	—	53.9	2.1	14.8	27.5	—	.6	1480
	a. p.,	10.7	48.0	1.9	13.1	24.6	—	.6	1320
Shoulder,	e. p.,	—	51.2	2.3	12.9	32.5	—	.6	1660
	a. p.,	12.4	44.9	2.1	11.6	28.3	—	.5	1450
Side,	e. p.,	—	34.4	3.2	8.8	52.5	—	.4	2440
	a. p.,	11.5	30.4	2.8	7.8	46.5	—	.4	2160
Pork (pickled, salted and smoked.									
Bacon,	e. p.,	—	18.8	4.8	9.6	64.0	—	3.3	2950
	a. p.,	7.7	17.4	4.4	8.8	59.1	—	3.1	2720
Ham,	e. p.,	—	40.3	3.6	15.8	36.9	—	3.6	1905
	a. p.,	13.6	34.8	3.1	13.8	31.7	—	3.2	1640
Shoulder,	e. p.,	—	45.0	3.8	15.4	30.9	—	5.0	1640
	a. p.,	18.2	36.8	3.1	12.6	25.3	—	4.1	1340
Salt, lean ends,	e. p.,	—	19.9	5.1	8.1	63.7	—	4.3	2905
	a. p.,	11.2	17.6	4.5	7.2	56,6	—	3.8	2580
Salt, fat,	a. p.,	—	7.9	5.4	1.8	81.9	—	2.9	3565
Pigs' feet, pickled,	e. p.,	—	68.2	1.4	15.8	14.1	—	.7	920
	a. p.,	35.5	44.6	.9	9.9	8.8	—	.5	575
Pork (cooked).									
Ribs, cooked,	a. p.,	—	33.6	3.1	24.1	35.7	—	1.7	2020
Steak, cooked,	a. p.,	—	33.2	3.3	19.3	43.1	—	1.1	2245
Sausage.									
Bologna,	e. p.,	—	60.0	2.4	18.1	16.7	0.3	2.8	1085
	a. p.,	3.3	55.2	2.4	17.7	18.7	—	2.9	1160
Frankfort,	a. p.,	—	57.2	2.3	19.0	17.7	1.1	2.6	1160
Pork,	a. p.,	—	39.8	3.1	12.6	42.0	1.1	1.7	2080

TABLE 13.—*(Continued)*.

a. p. = as purchased. e. p. = edible portion. See page 112.

KIND OF FOOD MATERIAL.		Refuse.	Water.	Unavailable nutrients.	AVAILABLE NUTRIENTS. Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel value per lb.
ANIMAL FOODS.		%	%	%	%	%	%	%	Calories.
Poultry and game (fresh).									
Chicken, broilers,	e. p.,	—	74.8	1.0	20.9	2.4	—	.8	520
	a. p.,	41.6	43.7	.7	12.4	1.3	—	.5	305
Fowl,	e. p.,	—	63.7	1.6	18.7	15.5	—	.8	1040
	a. p.,	25.9	47.1	1.2	13.3	11.7	—	.5	770
Goose,	e. p.,	—	46.7	2.5	15.8	34.4	—	.6	1800
	a. p.,	17.6	38.5	2.1	13.0	28.3	—	.5	1480
Turkey,	e. p.,	—	55.5	1.9	20.5	21.8	—	.8	1350
	a. p.,	22.7	42.4	1.6	15.6	17.5	—	.6	1065
Poultry and game (cooked and canned).									
Capon,	e. p.,	—	59.9	1.7	26.2	10.9	—	1.0	995
	a. p.,	10.4	53.6	1.5	23.5	9.8	—	.9	890
Turkey, roast,	a. p.,	—	67.5	1.3	17.1	10.9	2.4	.8	855
Plover, roast, canned,	a. p.,	—	57.7	1.7	21.7	9.7	7.6	1.6	985
Quail, canned,	a. p.,	—	66.9	1.6	21.1	7.6	1.7	1.1	780
Fish (fresh).									
Bass, black, whole,	e. p.,	—	76.7	1.0	20.0	1.6	—	.9	470
	a. p.,	54.8	34.6	.4	9.0	.8	—	.4	215
Blue fish,	e. p.,	—	78.5	1.0	18.8	1.1	—	1.0	420
	a. p.,	48.6	40.3	.5	9.7	.6	—	.5	220
Cod fish, dressed,	a. p.,	29.9	58.5	.5	10.8	.2	—	.6	225
Cod steaks,	e. p.,	—	79.7	.9	18.1	.5	—	.9	385
	a. p.,	9.2	72.4	.7	16.5	.5	—	.8	350
Flounder, whole,	e. p.,	—	84.2	.7	13.8	.6	—	1.0	300
	a. p.,	61.5	32.6	.3	5.2	.3	—	.4	115
Haddock,	e. p.,	—	81.7	.8	16.7	.3	—	.9	345
	a. p.,	51.0	40.0	.4	8.1	.2	—	.5	170
Halibut steak,	e. p.,	—	75.4	1.1	18.0	4.9	—	.8	570
	a. p.,	17.7	61.9	.9	14.8	4.2	—	.7	475
Lake trout,	e. p.,	—	70.8	1.3	17.3	9.8	—	.9	765
	a. p.,	48.5	36.6	.7	8.8	4.8	—	.5	380
Mackerel,	e. p.,	—	73.4	1.3	18.1	6.7	—	.9	650
	a. p.,	44.7	40.4	.7	9.9	4.0	—	.5	370
Weakfish,	e. p.,	—	79.0	.9	17.3	2.3	—	.9	445
	a. p.,	51.9	38.0	.5	8.3	1.0	—	.5	210
Whitefish, whole,	e. p.,	—	69.8	1.4	22.2	6.2	—	1.2	710
	a. p.,	53.5	32.5	.6	10.3	2.9	—	.5	330
Shell fish (fresh).									
Long clams, in shell,	e. p.,	—	85.8	1.0	8.3	.9	2.0	2.0	240
	a. p.,	41.9	49.9	.5	4.9	.6	1.1	1.1	145
R'nd clams, in shell,	e. p.,	—	86.2	.9	6.3	.4	4.2	2.0	215
	a. p.,	67.5	28.0	.3	2.0	.1	1.4	.7	70

TABLE 13.—*(Continued.)*

a. p. = as purchased. e. p. = edible portion. See page 112.

KIND OF FOOD MATERIAL.		Refuse.	Water.	Unavailable nutrients.	AVAILABLE NUTRIENTS. Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel value per lb.
ANIMAL FOODS. *Shell fish (fresh).*		%	%	%	%	%	%	%	Calories.
Oysters, in shell, -	e. p.,	—	86.9	.8	6.0	1.1	3.7	1.5	235
	a. p.,	81.4	16.1	.1	1.2	.2	.7	.3	45
Oysters, solids, -	a. p.,	—	88.3	.6	5.8	1.2	3.3	.8	225
Clams, round, solids,	a. p.,	—	80.8	1.0	10.3	1.0	5.2	1.7	340
Crabs, hard shells, -	e. p.,	—	77.1	1.4	16.1	1.9	1.2	2.3	425
	a. p.,	52.4	36.7	.6	7.7	.9	.6	1.1	200
Lobster, - - -	e. p.,	—	79.2	1.1	15.9	1.7	.4	1.7	400
	a. p.,	61.7	30.7	.4	5.7	.7	.2	.6	145
Fish (preserved and canned).									
Cod, salt, - -	e. p.,	—	53.5	6.8	20.9	.3	—	18.5	430
	a. p.,	24.9	40.2	5.1	15.5	.4	—	13.9	325
Cod, salt, boneless, -	e. p.,	—	55.0	5.5	24.9	.3	—	14.3	510
	a. p.,	1.6	54.8	4.6	27.7	.3	—	11.0	565
Halibut, smoked, -	e. p.,	—	49.4	5.0	20.1	14.3	—	11.3	1015
	a. p.,	7.0	46.0	4.8	18.7	13.3	—	10.4	945
Herring, smoked, -	e. p.,	—	34.6	5.2	35.8	15.0	—	9.9	1360
	a. p.,	44.4	19.2	2.8	19.9	8.4	—	5.6	760
Mackerel, salt, dressed, -	e. p.,	—	43.4	5.0	16.8	25.1	—	9.7	1415
	a. p.,	19.7	34.8	4.1	13.5	20.1	—	7.8	1135
Salmon, canned, -	e. p.,	—	63.5	1.9	21.1	11.5	—	2.0	915
	a. p.,	14.2	56.8	1.5	18.9	7.1	—	1.5	685
Sardines, canned, -	e. p.,	—	52.3	3.1	22.3	18.7	—	4.2	1250
	a. p.,	5.0	53.6	2.6	23.0	11.5	—	4.0	955
Lobster, canned, -	a. p.,	—	77.8	1.3	17.6	1.0	.4	1.9	400
Clams, canned, -	a. p.,	—	82.9	1.0	10.2	.8	3.0	2.1	290
Oysters, canned, -	a. p.,	—	83.4	.8	8.5	2.3	3.9	1.1	340
Eggs.									
Eggs, uncooked, -	e. p.,	—	73.7	1.1	13.0	10.0	—	.8	695
	a. p.,	11.2	65.5	1.1	11.5	8.8	—	.7	615
Eggs, boiled, - -	e. p.,	—	73.2	1.2	12.8	11.4	—	.6	755
	a. p.,	11.2	65.0	1.1	11.3	10.2	—	.5	670
Dairy products, etc.									
Whole milk, - -	a. p.,	—	87.0	.5	3.2	3.8	5.0	.5	310
Skim milk, - -	a. p.,	—	90.5	.3	3.3	.3	5.1	.5	170
Condensed milk, sweetened, -	a. p.,	—	26.9	1.2	8.5	7.9	54.1	1.4	1460
Cream, - - -	a. p.,	—	74.0	1.1	2.4	17.6	4.5	.4	860
Cheese, - - -	a. p.,	—	34.2	3.4	25.1	32.0	2.4	2.9	1885
Butter, - - -	a. p.,	—	11.0	4.9	1.0	80.8	—	2.3	3410
Oleomargarine, etc.,	a. p.,	—	9.5	5.7	1.2	78.9	—	4.7	3335
Lard, cottolene, etc.,	a. p.,	—	—	5.0	—	95.0	—	—	3985

TABLE 13.—(*Continued.*)

a. p. = as purchased. e. p. = edible portion. See page 112.

KIND OF FOOD MATERIAL.	Refuse.	Water.	Unavailable nutrients.	AVAILABLE NUTRIENTS.				
				Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel value per lb.
ANIMAL FOOD.	%	%	%	%	%	%	%	Calories.
Miscellaneous.								
Gelatin, a. p.,	—	13.6	3.2	88.7	.1	—	1.6	2125
Calf's-foot jelly, a. p.,	—	77.6	.3	4.2	—	17.4	.5	410
VEGETABLE FOODS.								
Cereals, etc.								
Barley, pearled,	—	11.5	4.0	6.6	1.0	76.1	.8	1630
Buckwheat flour,	—	13.6	3.5	5.2	1.1	75.9	.7	1600
Buckwheat, self-raising,	—	11.6	4.9	6.7	1.1	71.5	4.2	1545
Corn (maize) flour,	—	12.6	3.6	5.8	1.2	76.3	.5	1625
Corn (maize) meal,	—	12.5	4.0	7.5	1.7	73.5	.8	1625
Corn (maize) preparations:								
Cerealine,	—	10.3	4.2	7.8	1.0	76.3	.4	1655
Hominy,	—	11.8	3.8	6.8	.5	76.9	.2	1625
Hominy, cooked,	—	79.3	.9	1.8	.2	17.4	.4	375
Oatmeal and rolled oats,	—	7.8	5.6	13.4	6.6	65.2	1.4	1795
Oatmeal, boiled,	—	84.5	.9	2.3	.5	11.3	.5	285
Rice,	—	12.3	3.7	6.5	.3	76.9	.3	1610
Rice, boiled,	—	72.5	1.1	2.3	.1	23.8	.2	505
Rye flour,	—	12.9	3.6	5.3	.8	76.9	.5	1610
Entire wheat flour,	—	11.4	4.5	10.7	1.7	70.9	.8	1645
Gluten flour,	—	12.0	4.6	11.0	1.6	70.1	.7	1630
Graham flour,	—	11.3	4.7	10.3	2.0	70.4	1.3	1640
Wheat flour, patent process:								
Low grade,	—	12.0	4.5	10.9	1.7	70.2	.7	1635
Bakers' grade,	—	11.9	4.2	10.3	1.4	71.7	.5	1640
Family and straight grade,	—	12.8	4.0	8.3	1.0	73.5	.4	1615
High grade,	—	12.4	4.0	8.7	.9	73.6	.4	1620
Wheat preparations:								
Breakfast foods,	—	9.6	4.5	9.3	1.6	74.0	1.0	1670
Macaroni,	—	10.3	4.5	10.4	.8	73.0	1.0	1640
Macaroni, cooked,	—	78.4	1.3	2.3	1.4	15.6	1.0	405
Spaghetti,	—	10.6	4.0	9.4	.4	75.1	.5	1640
Noodles,	—	10.7	4.2	9.1	.9	74.3	.8	1640
Bread:								
Brown,	—	43.6	2.8	4.2	1.6	46.2	1.6	1035
Corn (johnnycake),	—	38.9	3.5	6.5	4.2	45.2	1.7	1170
Rye,	—	35.7	3.4	7.3	.5	52.0	1.1	1160
Graham,	—	35.7	3.4	6.9	1.6	51.3	1.1	1185
Whole wheat,	—	38.4	3.2	7.5	.8	49.1	1.0	1125
White wheat,	—	35.3	3.3	7.1	1.2	52.3	.8	1195
Biscuit, soda,*	—	22.9	4.7	7.2	12.3	51.8	1.1	1655
Rolls,	—	29.2	3.6	6.9	3.7	55.8	.8	1360
Toasted bread,	—	24.0	4.1	8.9	1.4	60.3	1.3	1390

* Made from wheat flour, raised with baking soda.

TABLE 13.—*(Continued.)*

a. p. = as purchased. e. p. = edible portion. See page 112.

KIND OF FOOD MATERIAL.	Refuse.	Water.	Unavailable nutrients.	AVAILABLE NUTRIENTS. Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel value per lb.
VEGETABLE FOODS. *Cereals, etc.*	%	%	%	%	%	%	%	Calories.
Crackers:								
Boston (split),	—	7.5	5.0	8.5	7.7	69.9	1.4	1830
Milk cream,	—	6.8	5.0	7.5	10.9	68.5	1.3	1920
Graham,	—	5.4	4.8	7.7	8.5	72.5	1.1	1900
Oyster,	—	4.8	5.4	8.8	9.5	69.3	2.2	1905
Soda,	—	5.9	4.9	7.6	8.2	71.8	1.6	1870
Water,	—	6.8	5.0	8.3	7.9	70.6	1.4	1850
Cakes, cookies, etc.:								
Bakers' cake,	—	31.4	3.3	4.8	4.1	55.8	.6	1335
Coffee cake,	—	21.3	3.8	5.5	6.8	61.9	.7	1580
Gingerbread,	—	18.8	4.3	4.5	8.1	62.1	2.2	1620
Sponge cake,	—	15.3	4.4	4.8	9.6	64.5	1.4	1735
Drop cake,	—	16.6	4.5	5.9	13.2	59.2	.6	1805
Molasses cookies,	—	6.2	4.7	5.6	7.8	74.0	1.7	1855
Sugar cookies,	—	8.3	4.5	5.4	9.2	71.6	1.0	1865
Ginger snaps,	—	6.3	4.7	5.0	7.7	74.3	2.0	1845
Wafers,	—	6.6	4.8	6.7	7.7	73.0	1.2	1855
Doughnuts,	—	18.3	4.8	5.2	18.9	52.1	.7	1895
Pie, pudding, etc.:								
Pie, apple,	—	42.5	3.1	2.4	8.8	41.8	1.4	1215
Pie, custard,	—	62.4	2.2	3.2	5.7	25.7	.8	795
Pie, squash,	—	64.2	2.4	3.4	7.6	21.4	1.0	800
Pudding, Indian meal,	—	60.7	2.5	4.5	4.3	26.9	1.1	785
Pudding, rice custard,	—	59.4	2.1	3.2	4.1	30.7	.5	825
Pudding, tapioca,	—	64.5	1.0	2.8	2.9	28.2	.6	715
Sugars, starches, etc.								
Sugar, granulated,	—	—	—	—	—	100.0	—	1790
Sugar, pulverized,	—	—	—	—	—	100.0	—	1790
Sugar, brown,	—	—	—	—	—	95.0	—	1700
Sugar, maple,	—	—	—	—	—	82.8	—	1485
Molasses,	—	—	—	—	—	70.0	—	1255
Maple syrup,	—	—	—	—	—	71.0	—	1270
Cornstarch,	—	—	—	—	—	90.0	—	1715
Tapioca,	—	11.4	.1	.3	.1	88.0	.1	1685
Sago,	—	12.2	1.4	7.7	.4	78.1	.2	1665
Vegetables.								
Asparagus, fresh,	—	94.0	.7	1.3	.2	3.3	.5	95
Asparagus, cooked,	—	91.6	1.0	1.7	3.0	2.1	.6	195
Beans, Lima, green, e. p.,	—	68.5	2.7	5.3	.6	21.6	1.3	525
Beans, Lima, green, a. p.,	55.0	30.8	1.2	2.4	.3	9.7	.6	240

TABLE 13.—(*Continued.*)

a. p. = as purchased. e. p. = edible portion. See page 112.

KIND OF FOOD MATERIAL.	Refuse.	Water.	Unavailable nutrients.	AVAILABLE NUTRIENTS.				
				Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel value per lb.
VEGETABLE FOODS. *Vegetables.*	%	%	%	%	%	%	%	Calories.
Beans, Lima, dried,	—	10.4	6.7	12.8	1.4	65.6	3.1	1565
Beans, string, fresh, e. p.,	—	89.2	1.0	1.7	.3	7.2	.6	180
Beans, string, fresh, a. p.,	7.0	83.0	.9	1.6	.3	6.7	.5	165
Beans, string, cooked,*	—	95.3	.5	.6	1.0	1.9	.7	90
Beans, white, dried,	—	12.6	7.5	15.8	1.6	59.9	2.6	1530
Beans, baked,	—	68.9	2.8	4.8	2.3	19.6	1.6	565
Beets, fresh, e. p.,	—	87.5	1.0	1.2	.1	9.4	.8	205
Beets, fresh, a. p.,	20.0	70.0	.8	1.0	.1	7.4	.7	160
Beets, cooked,*	—	88.6	1.2	1.7	.1	7.2	1.2	170
Beet "greens," cooked,*	—	89.5	1.2	1.7	3.1	3.2	1.3	220
Cabbage, e. p.,	—	91.5	.7	1.2	.3	5.5	.8	140
Cabbage, a. p.,	15.0	77.7	.6	1.1	.2	4.7	.7	115
Carrots, fresh, e. p.,	—	88.2	1.0	.7	.4	8.9	.8	200
Carrots, fresh, a. p.,	20.0	70.6	.6	.8	.2	7.1	.7	155
Carrots, cooked,*	—	3.5	6.9	5.8	3.2	76.9	3.7	1700
Cauliflower,	—	92.3	.7	1.3	.5	4.7	.5	135
Celery, e. p.,	—	94.5	.6	.8	.1	3.2	.8	80
Celery, a. p.,	20.0	75.6	.4	.7	.1	2.6	.6	65
Sweet corn, green, e. p.,	—	75.4	1.8	2.3	1.0	19.0	.5	445
Sweet corn, green, a. p.,	61.0	29.4	.7	.9	.4	7.4	.2	175
Cucumbers, e. p.,	—	95.4	.4	.6	.2	3.0	.4	75
Cucumbers, a. p.,	15.0	81.1	.3	.5	.2	2.6	.3	65
Egg plant,	—	92.9	.6	.9	.3	4.9	.4	120
Lettuce, e. p.,	—	94.7	.5	.9	.3	2.9	.7	85
Lettuce, a. p.,	15.0	80.5	.5	.7	.2	2.5	.6	70
Onions, fresh, e. p.,	—	87.6	.8	1.2	.3	9.6	.5	215
Onions, fresh, a. p.,	10.0	78.9	.7	1.1	.3	8.6	.4	195
Onions, cooked,*	—	91.2	.8	.9	1.6	4.8	.7	175
Parsnips, e. p.,	—	83.0	1.2	1.2	.5	13.0	1.1	290
Parsnips, a. p.,	20.0	66.4	1.0	1.0	.4	10.4	.8	230
Peas, dried,	—	9.5	7.6	17.3	.9	62.5	2.2	1580
Peas, green, e. p.,	—	74.6	2.2	5.2	.5	16.7	.8	430
Peas, green, a. p.,	45.0	40.8	1.2	2.7	.2	9.6	.5	235
Peas, green, cooked,*	—	73.8	2.5	5.1	3.1	14.4	1.1	490
Potatoes, e. p.,	—	78.3	1.4	1.7	.1	17.7	.8	370
Potatoes, a. p.,	20.0	62.6	1.2	1.3	.1	14.2	.6	295
Potatoes, cooked, boiled,	—	75.5	1.7	1.9	.1	20.0	.8	415
Potatoes, mashed and creamed,	—	75.1	2.0	2.0	2.7	17.1	1.1	475
Pumpkins, e. p.,	—	93.1	.6	.7	.1	5.0	.5	110
Pumpkins, a. p.,	50.0	46.5	.3	.3	.1	2.6	.2	60
Radishes, e. p.,	—	91.8	.7	1.0	.1	5.6	.8	130
Radishes, a. p.,	30.0	64.3	.5	.7	.1	3.9	.5	90
Rhubarb, e. p.,	—	94.4	.6	.4	.6	3.5	.5	100
Rhubarb, a. p.,	40.0	56.6	.3	.3	.4	2.1	.3	60
Squash, e. p.,	—	88.3	.9	1.1	.5	8.6	.6	205
Squash, a. p.,	50.0	44.2	.4	.5	.2	4.4	.3	100

* With butter, etc., added.

TABLE 13.—*(Continued.)*

a. p. = as purchased. e. p. = edible portion. See page 112.

KIND OF FOOD MATERIAL.		Refuse.	Water.	Unavailable nutrients.	AVAILABLE NUTRIENTS. Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel value per lb.
VEGETABLE FOODS. *Vegetables.*		%	%	%	%	%	%	%	Calories.
Spinach, fresh,		—	92.3	1.0	1.6	.3	3.2	1.6	100
Spinach, cooked,*		—	89.8	1.1	1.6	3.7	2.7	1.1	235
Sweet potatoes, fresh,	e.p.,	—	69.0	2.1	1.3	.6	26.2	.8	545
	a.p.,	20.0	55.2	1.6	1.1	.5	20.9	.7	440
Sweet potatoes, cooked,*		—	51.9	3.0	2.2	1.9	40.3	.7	885
Tomatoes,		—	94.3	.4	.7	.4	3.8	.4	100
Turnips,	e. p.,	—	89.6	.8	1.0	.2	7.8	.6	175
	a. p.,	30.0	62.7	.5	.7	.1	5.5	.5	120
Vegetables (canned).									
Asparagus,		—	94.4	.6	1.2	.1	2.8	.9	80
Beans, baked,		—	68.9	2.7	4.8	2.3	19.7	1.6	555
Beans, string,		—	93.7	.7	.8	.1	3.7	1.0	90
Beans, Lima,		—	79.5	1.7	3.0	.3	14.3	1.2	335
Sweet corn,		—	76.1	1.7	2.1	1.1	18.3	.7	430
Peas, green,		—	85.3	1.4	2.7	.2	9.6	.8	235
Succotash,		—	75.9	1.8	2.7	.9	18.0	.7	425
Tomatoes,		—	94.0	.5	.9	.2	3.9	.5	100
Fruits, etc. (fresh).									
Apples,	e. p.,	—	84.6	1.6	.3	.5	12.8	.2	260
	a. p.,	25.0	63.3	1.2	.3	.3	9.7	.2	195
Apricots,	e. p.,	—	85.0	1.5	.9	—	12.2	.4	240
	a. p.,	6.0	79.9	1.5	.8	—	11.4	.4	220
Bananas,	e. p.,	—	75.3	2.7	1.0	.5	19.9	.6	400
	a. p.,	35.0	48.9	1.6	.6	.4	13.0	.5	265
Blackberries,		—	86.3	1.5	1.0	.9	9.9	.4	235
Cherries,	e. p.,	—	80.9	2.0	.8	.7	15.1	.5	320
	a. p.,	5.0	76.8	1.9	.7	.7	14.4	.5	305
Cranberries,		—	88.9	1.2	.3	.5	8.9	.2	190
Currants,		—	85.0	1.7	1.2	—	11.6	.5	230
Figs,		—	79.1	2.2	1.2	—	17.0	.5	330
Grapes,	e. p.,	—	77.4	2.4	1.1	1.4	17.3	.4	390
	a. p.,	25.0	58.0	1.7	.8	1.1	13.1	.3	300
Huckleberries,		—	81.9	2.0	.5	.5	14.9	.2	300
Lemons,	e. p.,	—	89.3	1.2	.8	.6	7.7	.4	180
	a. p.,	30.0	62.5	.9	.5	.4	5.4	.3	125
Muskmelons,	e. p.,	—	89.5	1.1	.5	—	8.4	.5	160
	a. p.,	50.0	44.8	.6	.3	—	4.1	.2	80
Oranges,	e. p.,	—	86.9	1.4	.6	.2	10.5	.4	210
	a. p.,	27.0	63.4	1.1	.5	.1	7.6	.3	150
Pears,	e. p.,	—	84.4	1.7	.5	.4	12.7	.3	255
	a. p.,	10.0	76.0	1.5	.4	.4	11.4	.3	230
Plums,	e. p.,	—	78.4	2.2	.8	—	18.2	.4	345
	a. p.,	5.0	74.5	2.1	.7	—	17.3	.4	325

* With butter, etc., added.

TABLE 13.—*(Continued.)*

a. p. = as purchased. e. p. = edible portion. See page 112.

KIND OF FOOD MATERIAL.		Refuse.	Water.	Unavailable nutrients.	AVAILABLE NUTRIENTS. Protein.	Fat.	Carbo-hydrates.	Ash.	Fuel value per lb.
VEGETABLE FOODS.		%	%	%	%	%	%	%	Calories.
Fruits, etc. (fresh).									
Prunes,	e. p.,	—	79.6	2.1	.7	—	17.1	.5	325
	a. p.,	6.0	75.4	2.0	.5	—	15.7	.4	295
Raspberries, black,		—	84.1	1.7	1.4	.9	11.4	.5	270
Strawberries,	e. p.,	—	90.4	1.0	.8	.5	6.8	.5	160
	a. p.,	5.0	85.9	1.0	.7	.5	6.4	.5	150
Watermelons,	e. p.,	—	92.4	.9	.3	.2	6.0	.2	125
	a. p.,	60.0	36.9	.3	.2	.1	2.4	.1	50
Fruits, etc. (dried).									
Apples,		—	28.1	7.5	1.3	2.0	59.6	1.5	1190
Apricots,		—	29.4	7.7	3.7	.9	56.5	1.8	1130
Citron,		—	19.0	8.3	.4	1.3	70.3	.7	1340
Currants,		—	17.2	8.6	1.9	1.5	67.0	3.8	1315
Dates,	e. p.,	—	15.4	8.8	1.6	2.5	70.7	1.0	1415
	a. p.,	10.0	13.8	8.0	1.5	2.2	63.6	.9	1275
Figs,		—	18.8	8.7	3.4	.3	67.0	1.8	1290
Raisins,	e. p.,	—	14.6	9.1	2.0	3.0	68.7	2.6	1410
	a. p.,	10.0	13.1	8.3	1.8	2.7	61.8	2.3	1270
Prunes,	e. p.,	—	22.3	8.3	1.6	—	66.1	1.7	1230
	a. p.,	15.0	19.0	7.0	1.4	—	56.1	1.5	1045
Fruits, etc. (canned).									
Apricots,		—	81.4	1.9	.7	—	15.7	.3	295
Blackberries,		—	40.0	6.1	.6	1.9	50.9	.5	1015
Blueberries,		—	85.6	1.6	.5	.5	11.5	.3	240
Cherries,		—	77.2	2.3	.9	.1	19.1	.4	365
Crab-apples,		—	42.4	5.7	.3	2.2	49.0	.4	985
Peaches,		—	88.1	1.3	.5	.1	9.8	.2	190
Pears,		—	81.1	1.9	.3	.3	16.2	.2	310
Strawberries (stewed),		—	74.8	2.6	.5	—	21.7	.4	400
Nuts.									
Almonds,	e. p.,	—	4.8	10.9	17.8	49.4	15.6	1.5	2685
	a. p.,	45.0	2.7	5.9	9.8	27.2	8.6	.8	1480
Butternuts,	e. p.,	—	4.4	11.4	23.7	55.1	3.2	2.2	2805
	a. p.,	86.0	.6	1.6	3.3	7.7	.5	.3	385
Chestnuts (fresh),	e. p.,	—	45.0	5.9	5.3	4.9	37.9	1.0	990
	a. p.,	16.0	37.8	5.0	4.4	4.1	31.9	.8	830
Cocoanuts,	e. p.,	—	14.1	9.2	4.8	45.5	25.1	1.3	2460
	a. p.,	49.0	7.2	4.6	2.5	23.1	12.9	.7	1260
Filberts,	e. p.,	—	3.7	10.7	13.3	58.8	11.7	1.8	2930
	a. p.,	52.0	1.8	5.1	6.4	28.3	5.6	.8	1405
Hickory nuts,	e. p.,	—	3.7	10.6	13.1	60.7	10.3	1.6	2980
	a. p.,	62.0	1.4	4.0	4.9	23.2	3.9	.6	1130
Peanuts,	e. p.,	—	9.2	10.7	21.9	34.7	22.0	1.5	2255
	a. p.,	25.0	6.9	8.1	16.6	26.2	16.6	1.1	1525

STUDIES OF DIETARIES OF COLLEGE STUDENTS AND OF MEMBERS OF FAMILIES OF PROFESSIONAL MEN.

REPORTED BY W. O. ATWATER AND R. D. MILNER.

As an important part of a more general inquiry into the subject of food economy, the Station has made studies of dietaries in order to obtain information concerning the dietary customs and actual food consumption of people in different localities and conditions of living. Such information, taken in connection with the composition, digestibility, and actual nutritive value of food materials, as discussed to some extent on preceding pages of this Report,* and the fundamental laws of nutrition, as revealed by experimental inquiries such as those made by the Station with men, and to be made, as it is hoped, with animals, in the Respiration Calorimeter, will gradually make it possible to point out the more common dietary errors, and to suggest methods of improvement to the advantage of both health and purse.

Although the number of dietary studies already made is quite large the results emphasize the importance of continued research along these lines. Fortunately, the interest of public and private institutions in the subject is increasing, and inquiries are now being made in different parts of the country by experiment stations, colleges, and various organizations, as well as by private individuals, both in coöperation with the United States Department of Agriculture and independently, so that the much needed information is accumulating more rapidly than would otherwise be possible.

In previous Reports of the Station accounts of forty-seven dietary studies have been given, comprising ten of farmers' families, nine of mechanics' families, nine of professional men's families, five of students' boarding clubs, and fourteen miscellaneous studies. In the present Report details are given of nine additional studies, including two made in the Connecticut Hospital for the Insane, five of dietaries of individual college students, one of an individual professional man, and one of a

* See pages 69–123.

professional man's family. The main results of these inquiries, including all the data used in the computations, are given in the following statements and tables. The dietary studies in the State Hospital for the Insane are, however, treated briefly by themselves in the succeeding article.

Methods.—The methods of dietary study followed by the Station have been fully described in former Reports.* The general plan includes (1) determinations of the amounts and costs of all the different food materials on hand at the beginning of, purchased during, and remaining on hand at the end of the investigations; (2) when practicable, the collection and analysis of kitchen and table waste; (3) a record of the weight, age, sex, and occupation of the different members of the group under observation, and the number of meals taken by each. From these data, and those for the composition of food materials, as determined by analyses of samples of the materials actually used or as assumed from averages of analyses of similar materials, the total amounts of protein, fats, and carbohydrates in the dietary and the amounts consumed per man per day are computed.

In carrying out the studies here reported the usual methods were followed as far as possible. In the two dietary studies carried out in the Hospital for the Insane (Nos. 253 and 254), the methods were necessarily somewhat modified. For instance, the various kitchens of the Hospital are served each day with raw materials from the general supply. In making a study in two of the buildings, therefore, it was not practicable to take an inventory of the materials on hand at the beginning and end of the study. The usual data concerning the kinds and amounts of foods consumed were obtained by keeping record of the weight of all the food materials used in the kitchen in the preparation of each meal. Weights were also taken of all materials sent from the kitchen to the dining room, and returned from the dining room to the kitchen. Considerable of the data thus obtained were, therefore, for the cooked foods actually eaten. In estimating the amounts of nutrients contained in these materials the composition was calculated from the total weight of the cooked product and the weights and composition of the raw ingredients used in preparing them.

In the studies of three individual college students (Nos. 318, 319, and 320), there were also some modifications of the usual methods. The data concerning the kinds and amounts of food actually consumed were obtained by the students, each of whom weighed, at the table, all of the food that was served to him for each meal, and recorded the weight together with such information as he could give concerning the character of the food, the method of preparing it, etc. In these studies the large majority of the statistics are, therefore, for cooked food materials as prepared for the table. It was not possible to make analyses of samples of the foods eaten nor to get data by which to calculate the composition of the cooked foods from the weights and composition of their ingredients. The percentages of nutrients in the foods were assumed to be the same as in similar cooked food materials, the composition of which had been already determined or computed. But it is obvious that the composition of such materials will vary widely, according to the recipes used in their preparation. The results of these studies, therefore, may be considered less reliable than the

* See Reports of this Station for 1891–96.

results of studies made according to the usual method; but they serve the purpose for which they were made and give a fair indication of the food consumption of the subjects.

Composition of food materials.—No analyses of food materials were made in connection with these studies. Most of the materials used were staple articles of diet, and their composition was assumed to be the same as the average composition of similar materials given in Bulletin 28, revised, of the Office of Experiment Stations of the United States Department of Agriculture.* In some of the studies, however, it was necessary to take the weights of the cooked foods as they were used. In several of these cases the percentage composition was calculated from the weights of the cooked foods and the weights and composition of the raw ingredients used in preparing them. The percentages of nutrients assumed for the cooked foods, according to such computation, are given in Table 14. Where it was impossible to obtain the weight of the raw ingredients the composition of the cooked food was assumed from analyses of similar foods. The reference numbers opposite the names of the various materials in the first table of each dietary study refer to the corresponding numbers in Table 14. In the case of the materials for which no reference number is given the percentage composition was taken from the Bulletin referred to above.

Details of the individual studies.—The introductory statements for each dietary study give the statistics concerning the number of persons in the study, the number of meals eaten by each, etc. The first table for each study gives the amounts, and the costs where known, of the different food materials used during the period of the study. The second table in each case gives the quantities of nutrients per man or per person per day furnished by the different groups of food materials, and the percentages which the different kinds of food and the nutrients contained in them make of the total food and total nutrients of the dietary. It shows also the fuel values of the nutrients and the amounts of nutrients and energy wasted.

Waste.—The words "refuse" and "waste" are ordinarily used somewhat indiscriminately. In general, "refuse" in animal food represents inedible material, although bone, tendon, etc., which are classed as refuse may be utilized for soup. The refuse of vegetable foods, such as parings, seeds, etc., represent not only inedible material, but also more or less edible material, according to the care used in preparation. As distinguished from refuse, the waste includes the edible portions of food, as pieces of meat, bread, etc., which might be saved and utilized, but are actually thrown away with the refuse.

In the studies here reported the refuse and the waste were separated as completely as practicable, and the latter was collected and either dried and analyzed, or the nutrients calculated from the weights and assumed percentage composition of the different food materials making up the waste.

The table following shows the percentage of nutrients in some of the food materials used in some of the dietaries here reported. The majority of these percentages were calculated from the weights and composition of the raw ingredients used in preparing the foods.

* The Chemical Composition of American Food Materials. By W. O. Atwater and A. P. Bryant.

TABLE 14.

Percentage of nutrients in some of the food materials used in the following dietaries:

Ref. No.	FOOD MATERIALS.	Protein.	Fat.	Carbo-hydrates.
	Animal Food.	%	%	%
1	Beef,	32.5	2.2	—
2	Gravy,	1.9	.2	12.5
3	Corned beef hash,	9.6	6.0	12.0
4	Scramble,	8.8	7.7	11.8
5	Soup,	2.6	.7	4.7
6	Soup,	7.0	3.6	9.1
7	Ham,	13.6	33.4	—
8	Cod, salt (stewed),	8.0	7.8	21.6
9	Cod, creamed,	11.0	.9	3.0
10	Soup (dried residue),	29.7	27.7	35.5
11	Butter,	1.1	86.2	—
12	Milk,	3.4	4.4	4.8
	Vegetable Food.			
13	Wheatlet, cooked,	2.8	.5	11.5
14	Wheat, cooked,	2.0	.3	12.8
15	Cornmeal mush,	1.4	.4	11.4
16	Oatmeal mush,	2.5	1.1	9.9
17	Rice, boiled,	1.7	.1	17.1
18	Bread, corn,	8.5	2.7	47.3
19	Bread, ginger,	5.4	9.5	64.7
20	Bread, graham,	8.6	1.3	54.3
21	Bread, wheat,	9.4	1.2	53.2
22	Bread,	8.4	2.0	47.5
23	Wheat breakfast food,	11.4	.6	80.4
24	Biscuit, raised,	8.4	6.5	53.9
25	Spaghetti,	11.8	1.6	73.1
26	Cake, tea,	7.1	9.0	68.5
27	Cookies, ginger,	5.8	6.2	80.8
28	Ginger snaps,	5.9	8.7	77.7
29	Cookies, molasses,	7.2	8.7	75.7
30	Cookies, sugar,	7.1	9.9	74.4
31	Doughnuts,	6.7	21.6	53.9
32	Doughnuts,	6.6	23.3	46.7
33	Griddle cakes,	13.0	6.0	35.7
34	Pie, peach,	4.1	9.9	37.8
35	Pudding, bread,	3.2	2.0	14.7
36	Pudding, bread,	3.4	4.4	19.0
37	Pudding, bread,	4.8	5.2	22.5
38	Pudding, Indian meal,	1.8	3.8	16.5
39	Pudding, rice,	1.8	.6	21.6
40	Pudding, rice,	3.1	2.7	13.4
41	Pudding, tapioca,	3.8	3.0	25.3
42	Pudding, tapioca,	1.7	4.3	19.6
43	Custard,	4.0	4.1	20.8
44	Fish dressing,	6.9	13.7	36.8
45	Rock candy,	—	—	100.0
46	Cocoa,	1.2	1.6	9.0
47	Peach sauce,	1.5	.3	29.9
48	Prune sauce,	1.1	—	40.1
49	Coffee jelly,	1.0	.1	27.1
50	Wet waste,	14.5	1.8	82.0

No. 316. DIETARY OF A COLLEGE STUDENT AT MIDDLETOWN, CONN.

This is the dietary of a college student, about 21 years of age, who boarded himself during a summer vacation, and for three weeks made careful record of all the food materials he used. His food, which he bought each day as needed, consisted largely of materials already cooked or otherwise prepared for eating. The proportion of vegetable food in this dietary is larger than usual, which is explained partly by his personal preference and partly by the fact that such food is obtainable in large variety ready for use. A quart of milk was used each day. Canned meats were purchased rather than fresh, because they required no cooking. The subject was in good health, weighed about 160 pounds at the beginning of the study, and gained slightly in weight during the study. He was engaged in mental work about eight hours a day, and rode from five to fifteen miles each day on his bicycle for exercise. The study is divided into three periods of one week each.

TABLE 15.

Cost and weights of food materials used in dietary No. 316.*

[*Quantities per man per day.*]

Food Materials. ‡	Cost.	Weight.	
	$	Lbs.	Oz.
Food Purchased.			
Animal Food.			
Beef:			
Steak, round,	.39	2	2.5
Roast, canned,	.42	3	4.0
Dried, smoked,	.15	—	7.5
Corned, canned,	.22	1	9.0
Pork: Lard,	—	—	2.0
Fish: Salmon, canned,	.35	1	14.0
Eggs,	.54	3	6.0
Butter,	—	—	1.0
Milk,	1.11	49	8.5
Milk, condensed,	.08	—	10.0
Total animal food,	**3.26**	**63**	**.5**
Vegetable Food.			
Oatmeal,	—	—	12.0
Rolls,	.46	6	1.0
Biscuit,	.15	1	13.5
Biscuit, shredded,	.40	2	8.5
Bread,	.07	1	7.0
Crackers, milk,	.03	—	4.0
Crackers, soda,	.02	—	2.0
Cakes, cup,	.06	—	8.5
Food Purchased.			
Vegetable Food (Con.)			
Cake, jelly,	.10	—	10.5
Cookies,	.02	—	6.0
Cookies, fruit,	.02	—	1.5
Cream puffs,	.02	—	2.5
Ginger snaps,	.08	—	12.0
"Rusk,"	.05	—	8.5
Sponge wafers,	.18	1	10.0
Pie, huckleberry,	.17	1	7.0
Pie, lemon,	.03	—	6.0
Pie, prune,	.10	1	—
Sugar,	.39	5	11.0
Beans, baked, canned,	.58	11	7.5
Peas, canned,	.04	—	9.5
Catsup,	.03	—	7.0
Apples,	—	—	1.0
Bananas,	.15	1	14.5
Dates,	.08	—	14.0
Plums,	—	—	2.0
Prunes,	.04	—	3.5
Ginger ale,	.10	—	7.0
Total veg. food,	**3.37**	**41**	**14.5**
Total food,	**6.63**	**105**	**6.0**

* All weights, unless otherwise specified, are of the edible material free from bone, skin, etc.

‡ The percentage composition of all materials used in this dietary was taken from Bulletin 28, of the Office of Experiment Stations of the U. S. Dept. of Agriculture.

TABLE 15.—(*Continued.*)

FOOD MATERIALS.	Cost.	Weight.		FOOD MATERIALS.	Cost.	Weight.	
FOOD WASTED.	$	Lbs.	Oz.	FOOD WASTED.	$	Lbs.	Oz.
Animal Food.				*Vegetable Food.*			
Beef, corned, canned,	—	—	2.5	Beans, baked, canned,	—	1	12.0
Beef, roast, canned, -	—	—	7.0	Dates, - - -	—	—	5.5
Salmon, canned, -	—	—	2.0				
Eggs, - - -	—	—	2.0	Total veg. food, -	—	**2**	**1.5**
Milk, - - -	—	—	8.5				
				Total food, - -	—	**3**	**7.5**
Total animal food,	—	**1**	**6.0**				

TABLE 16.

Weights and percentages of food materials and nutritive ingredients used in dietary study No. 316, first period.

[*Quantities per man per day.*]

FOOD MATERIALS.	WEIGHTS. Food materials.	WEIGHTS. NUTRIENTS. Protein.	WEIGHTS. NUTRIENTS. Fat.	WEIGHTS. NUTRIENTS. Carbo-hydrates.	Fuel value.	PERCENTAGES OF TOTAL FOOD. Food materials.	PERCENTAGES OF TOTAL FOOD. NUTRIENTS. Protein.	PERCENTAGES OF TOTAL FOOD. NUTRIENTS. Fat.	PERCENTAGES OF TOTAL FOOD. NUTRIENTS. Carbo-hydrates.	Fuel value.
FOOD PURCHASED.	Gm.	Gm.	Gm.	Gm.	Cal.	%	%	%	%	%
Animal Food.										
Beef, veal, mutton, -	216	56	26	—	—	8.7	31.9	20.5	—	—
Pork, lard, etc., -	7	—	7	—	—	.3	—	5.6	—	—
Eggs, - - -	90	13	9	—	—	3.6	7.5	7.4	—	—
Butter, - - -	4	—	4	—	—	.2	—	2.9	—	—
Milk, - - -	985	32	40	49	—	39.5	18.4	30.8	8.2	—
Milk, condensed, -	41	4	3	22	—	1.7	2.0	2.7	3.7	—
Total animal food,	**1343**	**105**	**89**	**71**	**1530**	**54.0**	**59.8**	**69.9**	**11.9**	**35.0**
Vegetable Food.										
Cereals, - - -	485	39	28	299	—	19.5	22.3	21.7	49.5	—
Sugars and starches,	135	—	—	135	—	5.4	—	—	22.4	—
Vegetables, - -	492	31	11	91	—	19.8	17.7	8.4	15.0	—
Fruits, - - -	33	1	—	7	—	1.3	.2	—	1.2	—
Total veg. food, -	**1145**	**71**	**39**	**532**	**2835**	**46.0**	**40.2**	**30.1**	**88.1**	**65.0**
Total food, - -	**2488**	**176**	**128**	**603**	**4365**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
FOOD WASTED.										
Animal, - - -	—	2	2	1	30	—	1.3	1.6	.2	.7
Vegetable, - -	—	8	3	23	155	—	4.5	2.2	3.7	3.5
Total, - - -	—	**10**	**5**	**24**	**185**	—	**5.8**	**3.8**	**3.9**	**4.2**
FOOD ACTUALLY EATEN.										
Animal, - - -	—	103	83	74	1500	—	58.5	68.3	11.7	34.4
Vegetable, - -	—	63	36	509	2680	—	35.7	27.9	84.4	61.4
Total, - - -	—	**166**	**119**	**583**	**4180**	—	**94.2**	**96.2**	**96.1**	**95.8**

TABLE 17.

Weights and percentages of food materials and nutritive ingredients used in dietary study No. 316, second period.

[*Quantities per man per day.*]

Food Materials.	Weights.					Percentages of Total Food.				
	Food materials.	Nutrients.			Fuel value.	Food materials.	Nutrients.			Fuel value.
		Protein.	Fat.	Carbo-hydrates.			Protein.	Fat.	Carbo-hydrates.	
Food Purchased.	Gm.	Gm.	Gm.	Gm.	Cal.	%	%	%	%	%
Animal Food.										
Beef, veal, mutton, -	164	42	36	—	—	6.8	26.2	27.7	—	—
Fish, etc., - -	65	14	8	—	—	2.7	8.9	6.0	—	—
Eggs, - - -	85	13	9	—	—	3.5	7.9	6.7	—	—
Milk, - - -	1155	38	46	58	—	47.9	23.9	35.0	10.9	—
Total animal food,	**1469**	**107**	**99**	**58**	**1595**	**60.9**	**66.9**	**75.4**	**10.9**	**39.3**
Vegetable Food.										
Cereals, - - -	401	31	24	247	—	16.6	19.4	17.8	46.6	—
Sugar and starches, -	101	—	—	101	—	4.2	—	—	19.1	—
Vegetables, - -	285	20	7	56	—	11.8	12.3	5.4	10.5	—
Fruits, - - -	128	2	2	65	—	5.3	1.4	1.4	12.3	—
Total veg. food, -	**915**	**53**	**33**	**469**	**2450**	**37.9**	**33.1**	**24.6**	**88.5**	**60.4**
Unclassified, -	29	—	—	3	10	1.2	—	—	.6	.3
Total food, - -	**2413**	**160**	**132**	**530**	**4055**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Food Wasted.										
Animal, - - -	—	7	4	—	65	—	4.6	3.3	.1	1.6
Vegetable, - -	—	1	1	18	90	—	.3	.5	3.4	2.2
Total, - - -	—	**8**	**5**	**18**	**155**	—	**4.9**	**3.8**	**3.5**	**3.8**
Food Actually Eaten.										
Animal, - - -	—	100	95	58	1530	—	62.2	72.1	10.8	37.7
Vegetable, - -	—	52	32	451	2360	—	32.9	24.1	85.1	58.2
Unclassified, - -	—	—	—	3	10	—	—	—	.6	.3
Total, - - -	—	**152**	**127**	**512**	**3900**	—	**95.1**	**96.2**	**96.5**	**96.2**

TABLE 18.

Weights and percentages of food materials and nutritive ingredients used in dietary study No. 316, third period.

[*Quantities per man per day.*]

FOOD MATERIALS.	WEIGHTS.					PERCENTAGES OF TOTAL FOOD.				
	Food materials.	NUTRIENTS.			Food value.	Food materials.	NUTRIENTS.			Fuel value.
		Protein.	Fat.	Carbo-hydrates.			Protein.	Fat.	Carbo-hydrates.	
FOOD PURCHASED.	Gm.	Gm.	Gm.	Gm.	Cal.	%	%	%	%	%
Animal Food.										
Beef, veal, mutton, -	102	27	19	—	—	5.3	22.1	18.6	—	—
Fish, etc., - -	58	13	7	—	—	3.0	10.4	6.8	—	—
Eggs, - - -	45	7	5	—	—	2.4	5.5	4.6	—	—
Milk, - - -	1072	35	43	54	—	55.3	29.1	41.5	11.4	—
Total animal food,	**1277**	**82**	**74**	**54**	**1245**	**66.0**	**67.1**	**71.5**	**11.4**	**36.7**
Vegetable Food.										
Cereals, - - -	449	37	28	268	—	23.2	30.6	27.4	56.7	—
Sugars and starches,	135	—	—	135	—	7.0	—	—	28.6	—
Vegetables, - -	33	2	1	6	—	1.7	1.8	.8	1.4	—
Fruits, - - -	42	1	—	9	—	2.1	.5	.3	1.9	—
Total veg. food, -	**659**	**40**	**29**	**418**	**2150**	**34.0**	**32.9**	**28.5**	**88.6**	**63.3**
Total food, - -	**1936**	**122**	**103**	**472**	**3395**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
FOOD WASTED.										
Animal, - - -	—	**4**	**3**	—	**45**	—	**3.5**	**2.8**	—	**1.3**
FOOD ACTUALLY EATEN.										
Animal, - - -	—	78	71	54	1220	—	63.6	68.7	11.4	35.9
Vegetable, - -	—	40	29	418	2130	—	32.9	28.5	88.6	62.8
Total, - - -	—	**118**	**100**	**472**	**3350**	—	**96.5**	**97.2**	**100.0**	**98.7**
Average of 3 periods,	—	**145**	**115**	**522**	**3810**	—	—	—	—	—

No. 317. DIETARY OF A CHEMIST'S FAMILY AT MIDDLETOWN, CONN.

This dietary study of a professional man's family was carried on for the purpose of testing the practicability of substituting salt fish and dried legumes as sources of protein in a diet where ordinarily considerable quantities of meats were used. Salt cod fish was used in various preparations, and dried beans were made into "baked beans," bean soup and "old-fashioned bean porridge." In all other respects the diet was the same as usual, differing, however, from many dietaries in the large amount of dairy products, especially butter and milk, which were used. The study began with breakfast, November 8, 1899, and continued 9 days, with 27 meals. The family consisted of one man, 31 years of age, weighing 155 pounds; one woman, 29 years of age, weighing 120 pounds; and one boy, 5 years old, weighing about 45 pounds. The number of meals taken were as follows:

One man, - - - - - - - - - -	27 meals.
One woman (27 x .8 meal of man), equivalent to -	22 meals.
One boy (27 x .4 meal of man), equivalent to - -	11 meals.
Total number of meals equivalent to - - -	60 meals.
Equivalent to one man 20 days.	

TABLE 19.

Cost and weights of food materials used in dietary No. 317.*

FOOD MATERIALS. †	Cost.	Weight.	
	$	Lbs.	Oz.
FOOD PURCHASED.			
Animal Food.			
Beef, shoulder, clod, -	.34	2	13.0
Salt pork, - - -	.04	—	7.0
Lard, - - -	.03	—	5.5
Cod, boned, - -	.20	2	6.5
Oysters, solids, - -	.18	1	1.0
Eggs, - - -	.19	1	1.0
Butter, - - -	.69	2	14.0
Cheese, - - -	.07	—	7.0
Milk, - - -	.97	34	14.5
Cream, - - -	.09	—	12.0
Total animal food, -	2.80	47	1.5
Vegetable Food.			
Corn meal, - -	.02	—	13.0
Rye meal, - - -	.01	—	9.0
Wheat flour, - -	.12	3	13.5
Wheatlet, - - -	.08	1	2.0
Shredded wheat, -	.07	—	7.0
Bread, wheat, - -	.02	—	9.0
Crackers, milk, - -	.02	—	3.5
Crackers, oyster, -	.05	—	7.5
Cornstarch, - -	.02	—	3.0
FOOD PURCHASED.			
Vegetable Food (Con.)			
Molasses, - -	.07	—	13.5
Maple syrup, - -	.02	—	2.0
Sugar, - - -	.16	2	9.0
Beans, dried, - -	.15	2	8.0
Potatoes, - - -	.05	4	3.0
Sweet potatoes, -	.07	4	3.5
Apples, - - -	.14	10	6.0
Grapes, § - -	.04	1	9.0
Grape preserves, -	.06	—	7.0
Peaches, canned, -	.13	1	—
Chestnuts, § - -	.05	—	8.0
English walnuts, § -	.02	—	4.0
Total veg. food, -	1.37	36	12.5
Total food, - -	4.17	83	14.0
FOOD WASTED.			
Animal Food.			
Beef, shoulder, clod,	—	—	.5
Milk, - - - -	—	—	.5
Total animal food,	—	—	1.0

* All weights, unless otherwise specified, are of edible material free from bone, skins, etc.

† The percentage composition of the materials used in this dietary was taken from Bulletin 28, of the Office of Experiment Stations of the U. S. Dept. of Agriculture.

§ As purchased.

TABLE 19.—(*Continued.*)

FOOD MATERIALS.	Cost.	Weight.		FOOD MATERIALS.	Cost.	Weight.	
FOOD WASTED. *Vegetable Food.*	$	Lbs.	Oz.	FOOD WASTED. *Vegetable Food (Con.)*	$	Lbs.	Oz.
Flour,	—	—	2.0	Beans, baked,	—	—	.5
Bread, brown,	—	—	1.3	Sweet potatoes,	—	—	.5
Bread, wheat,	—	—	.2	Total veg. food,	—	—	**6.5**
Wheatlet, cooked, *	—	—	2.0	Total food,	—	—	**7.5**

* See Ref. No. 13, Table 14.

TABLE 20.

Weights and percentages of food materials and nutritive ingredients used in dietary study No. 317.

[*Quantities per man per day.*]

FOOD MATERIALS.	WEIGHTS.				Fuel value.	PERCENTAGES OF TOTAL FOOD.				Fuel value.
	Food materials.	NUTRIENTS. Protein.	Fat.	Carbohydrates.		Food materials.	NUTRIENTS. Protein.	Fat.	Carbohydrates.	
FOOD PURCHASED.	Gm.	Gm.	Gm.	Gm.	Cal.	%	%	%	%	%
Animal Food.										
Beef, veal, mutton,	64	13	7	—	—	3.4	12.4	5.6	—	—
Pork, lard, etc.,	18	—	16	—	—	.9	.2	12.4	—	—
Fish,	79	15	1	1	—	4.1	15.3	.3	.3	—
Eggs,	24	3	2	—	—	1.2	3.5	1.9	—	—
Butter,	65	1	56	—	—	3.5	.6	42.9	—	—
Cheese,	10	3	3	—	—	.5	2.6	2.7	—	—
Milk,	791	26	32	39	—	41.6	25.9	24.4	10.1	—
Cream,	17	—	3	1	—	.9	.4	2.4	.3	—
Total animal food,	**1068**	**61**	**120**	**41**	**1535**	**56.1**	**60.9**	**92.6**	**10.7**	**49.8**
Vegetable Food.										
Cereals,	183	20	4	135	—	9.6	19.9	3.2	35.2	—
Sugars and starches,	84	1	—	77	—	4.4	.4	—	20.0	—
Vegetables,	246	17	2	77	—	13.0	16.3	1.4	20.0	—
Fruits,	321	2	4	54	—	16.9	2.5	2.8	14.1	—
Total veg. food,	**834**	**40**	**10**	**343**	**1665**	**43.9**	**39.1**	**7.4**	**89.3**	**50.2**
Total food,	**1902**	**101**	**130**	**384**	**3200**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
FOOD WASTED.										
Vegetable,*	—	**1**	—	**4**	**20**	—	**.6**	—	**1.0**	**.6**
FOOD ACTUALLY EATEN.										
Animal,	—	61	120	41	1535	—	60.9	92.6	10.7	49.8
Vegetable,	—	39	10	339	1645	—	38.5	7.4	88.3	49.6
Total,	—	**100**	**130**	**380**	**3180**	—	**99.4**	**100.0**	**99.0**	**99.4**

* The quantity of animal food wasted was too small to affect the final results per man per day.

No. 318. DIETARY OF A COLLEGE STUDENT AT MIDDLETOWN, CONN.

This study began with breakfast, December 5, 1899, and continued 6 days, with 18 meals. The subject was a college student about 20 years of age, and weighing 170 pounds. He was something of an athlete, and was taking active exercise in the gymnasium daily, besides more or less active exercise out of doors. For further description of this study, see page 125.

Table 21.

Weights of food materials consumed in dietary No. 318.*

Food Materials.	Ref. No.‡	Weight.		Food Materials.	Ref. No.‡	Weight.	
Food Consumed.		Lbs.	Oz.	Food Consumed.		Lbs.	Oz.
Animal Food.				*Vegetable Food (Con.)*			
Beef:				Oatmeal, boiled,	—	1	14.5
Boiled,	—	—	7.0	Pie, apple,	—	—	4.5
Corned, cooked,	—	—	7.5	Pudding, bread,	37	—	4.0
Corned, hash,	—	—	15.0	Rice, boiled,	—	1	—
Gravy,	2	—	6.5	Wheat, cooked,	14	1	2.5
Loin steak, broiled,	—	—	4.5	Cocoa,	46	—	6.0
Pork, loin, fried,	—	—	4.0	Sugar,	—	—	9.0
Fish, clam chowder,	—	—	17.0	Tapioca pudding,	—	—	4.0
Butter,	—	—	12.5	Beans, baked,	—	—	5.0
Milk,	—	14	1.5	Cabbage, cooked,	—	—	3.5
				Cabbage, chopped,	—	—	1.5
Total animal food,	—	**18**	**11.5**	Potatoes, cooked,	—	3	10.5
				Apples,	—	—	9.5
Vegetable Food.				Apple sauce,	—	—	4.0
Bread, brown,	—	1	6.5	Apples, baked,	—	—	3.5
Bread, corn,	—	—	5.0	Cranberry sauce,	—	—	3.5
Bread, wheat,	—	4	11.0	Jelly, coffee,	49	—	2.5
Biscuit, graham,	—	—	5.5				
Biscuit, shredded,	—	—	2.0	Total veg. food,	—	**19**	**14.0**
Cake, layer,	—	—	4.5				
Dumplings, apple,	—	—	8.5	Total food,	—	**38**	**9.5**
Gems, wheat,	—	—	11.0				

* All weights are of edible material.

‡ See pp. 126 and 127.

TABLE 22.

Weights and percentages of food materials and nutritive ingredients consumed in dietary study No. 318.

[*Quantities per man per day.*]

FOOD MATERIALS.	WEIGHTS.				Fuel value.	PERCENTAGES OF TOTAL FOOD.				Fuel value.
	Food materials.	NUTRIENTS.				Food materials.	NUTRIENTS.			
		Protein.	Fat.	Carbo-hydrates.			Protein.	Fat.	Carbo-hydrates.	
FOOD PURCHASED.	Gm.	Gm.	Gm.	Gm.	Cal.	%	%	%	%	%
Animal Food.										
Beef, veal, mutton, -	191	28	16	11	—	6.5	20.4	11.6	1.8	—
Pork, lard, etc., -	19	3	6	—	—	.6	2.3	4.1	—	—
Fish, - - -	81	2	1	5	—	2.8	1.1	.5	.9	—
Butter, - - -	60	1	51	—	—	2.1	.3	37.0	—	—
Milk, - - -	1064	35	42	53	—	36.5	25.2	30.8	8.8	—
Total animal food,	**1415**	**69**	**116**	**69**	**1645**	**48.5**	**49.3**	**84.0**	**11.5**	**38.1**
Vegetable Food.										
Cereals, - - -	981	60	19	388	—	33.6	43.2	14.0	64.6	—
Sugars and starches,	89	1	1	50	—	3.0	.7	.7	8.3	—
Vegetables, - -	325	9	1	64	—	11.2	6.5	.7	10.6	—
Fruits, - - -	107	—	1	30	—	3.7	.3	.6	5.0	—
Total veg. food, -	**1502**	**70**	**22**	**532**	**2670**	**51.5**	**50.7**	**16.0**	**88.5**	**61.9**
Total food, - -	**2917**	**139**	**138**	**601**	**4315**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

No. 319. DIETARY OF A COLLEGE STUDENT AT MIDDLETOWN, CONN.

This study began with breakfast, December 5, 1899, and continued 6 days, with 18 meals. The subject was a college student, about 20 years of age, and weighing about 160 pounds. He took no especially active exercise. For further description of this study, see page 125.

TABLE 23.

Weights of food materials used in dietary No. 319.*

FOOD MATERIALS.	Ref. No.‡	Weight. Lbs.	Weight. Oz.
FOOD PURCHASED.			
Animal Food.			
Beef:			
Boiled, - - -	—	—	5.5
Corned, cooked, -	—	—	5.0
Chopped, cooked, -	—	—	2.5
Corned, hash, -	—	—	11.5
Gravy, - - -	2	—	4.0
Loin steak, broiled,	—	—	3.5
Pork, loin, fried, -	—	—	3.5
Fish, clam chowder, -	—	—	11.0
Butter, - - -	—	—	10.0
Milk, - - -	—	3	13.5
Total animal food, -	—	**7**	**6.0**
Vegetable Food.			
Bread, brown, - -	—	—	8.0
Bread, corn, - -	—	—	7.0
Bread, graham, - -	—	—	10.5
Bread, wheat, - -	—	1	11.0
Biscuit, graham, -	—	—	7.0
Biscuit, shredded, -	—	—	1.0
Biscuit, wheat, - -	—	—	8.5
Cake, layer, - -	—	—	3.0
Vegetable Food (Con.)			
Crackers, - -	—	—	9.0
Dumplings, apple, -	—	—	5.0
Gems, wheat, - -	—	—	4.5
Oatmeal, boiled, -	—	2	10.0
Pie, apple, - -	—	—	6.5
Rice, boiled, - -	—	—	7.5
Wheat, cooked, -	14	—	5.5
Sugar, - - -	—	—	6.5
Cocoa, - - -	46	—	7.0
Tapioca pudding, -	—	—	3.5
Beans, baked, - -	—	—	10.5
Cabbage, cooked, -	—	—	4.5
Cabbage, chopped, -	—	—	2.5
Potatoes, cooked, -	—	1	12.5
Potatoes, creamed, -	—	—	4.5
Apple sauce, - -	—	—	3.0
Apples, baked, -	—	—	10.5
Cranberry sauce, -	—	—	3.5
Jelly, coffee, - -	49	—	5.0
Total veg. food, -	—	**15**	**1.5**
Total food, - -	—	**22**	**7.5**

* All weights are of edible material.

‡ See pp. 126 and 127.

TABLE 24.

Weights and percentages of food materials and nutritive ingredients consumed in dietary study No. 319.

[*Quantities per man per day.*]

FOOD MATERIALS.	WEIGHTS.					PERCENTAGES OF TOTAL FOOD.				
	Food materials.	Nutrients.			Fuel value.	Food materials.	Nutrients.			Fuel value.
		Protein.	Fat.	Carbo-hydrates.			Protein.	Fat.	Carbo-hydrates.	
FOOD CONSUMED.	Gm.	Gm.	Gm.	Gm.	Cal.	%	%	%	%	%
Animal Food.										
Beef, veal, mutton, -	151	24	13	7	—	8.9	26.8	12.9	1.8	—
Pork, lard, etc., -	16	3	5	—	—	1.0	3.0	5.1	—	—
Fish, etc., - -	52	1	—	—	—	3.1	1.1	.3	.8	—
Butter, - - -	47	—	40	3	—	2.8	.5	40.8	—	—
Milk, - - -	291	10	12	15	—	17.1	10.5	11.8	3.4	—
Total animal food,	**557**	**38**	**70**	**25**	**910**	**32.9**	**41.9**	**70.9**	**6.0**	**30.2**
Vegetable Food.										
Cereals, - -	718	44	24	277	—	42.3	48.0	24.9	65.5	—
Sugars and starches,	80	1	1	37	—	4.7	1.1	1.2	8.9	—
Vegetables, - -	237	8	2	44	—	14.0	8.6	2.2	10.3	—
Fruits, - - -	104	—	1	39	—	6.1	.4	.8	9.3	—
Total veg. food, -	**1139**	**53**	**28**	**397**	**2105**	**67.1**	**58.1**	**29.1**	**94.0**	**69.8**
Total food, - -	**1696**	**91**	**98**	**422**	**3105**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

No. 320. DIETARY OF A COLLEGE STUDENT AT MIDDLETOWN, CONN.

This study began with breakfast, December 5, 1899, and continued 6 days, with 18 meals. The subject was a college student, about 20 years of age, and weighing about 175 pounds. He was taking moderate exercise daily. For further description of this study, see page 125.

Table 25.

Weights of food materials used in dietary No. 320.*

Food Materials.	Ref. No.‡	Weight.		Food Materials.	Ref. No.‡	Weight.	
Food Consumed.		Lbs.	Oz.	Food Consumed.		Lbs.	Oz.
Animal Food.				*Vegetable Food (Con.)*			
Beef:				Cake, layer, - -	—	—	8.0
Boiled, - - - -	—	—	6.5	Crackers, - - -	—	—	2.0
Corned, cooked, -	—	—	7.5	Dumpling, apple, -	—	—	7.5
Corned, hash, -	—	—	15.0	Oatmeal, - - -	—	2	3.5
Gravy, - - - -	2	—	3.0	Pie, apple, - -	—	—	6.5
Loin steak, broiled,	—	—	3.5	Rice, boiled, - -	—	—	12.5
Pork, loin, fried, -	—	—	1.5	Cocoa, - - -	46	—	4.5
Fish, etc., clam chowder,	—	—	13.0	Sugar, - - -	—	—	9.0
Butter, - - - -	—	—	7.0	Tapioca pudding, -	—	—	4.5
Milk, - - - -	—	10	13.5	Beans, baked, -	—	—	7.0
				Cabbage, cooked, -	—	—	4.0
Total animal food, -	—	**14**	**6.5**	Potatoes, cooked, -	—	1	6.5
				Apples, - - -	—	—	2.5
Vegetable Food.				Apples, baked, -	—	—	8.5
Bread, brown, - -	—	—	4.0	Apple sauce, - -	—	—	3.0
Bread, graham, - -	—	2	—	Jelly, coffee, - -	49	—	3.0
Bread, wheat, - -	—	—	25.0				
Biscuit, shredded, -	—	—	6.0	Total veg. food, -	—	**13**	**2.0**
Custard, - - -	43	—	2.5	Total food, - -	—	**27**	**8.5**

* All weights are of edible material.

‡ See pp. 126 and 127.

TABLE 26.

Weights and percentages of food materials and nutritive ingredients consumed in dietary study No. 320.

[*Quantities per man per day.*]

FOOD MATERIALS.	WEIGHTS. Food materials.	WEIGHTS. NUTRIENTS. Protein.	WEIGHTS. NUTRIENTS. Fat.	WEIGHTS. NUTRIENTS. Carbohydrates.	Fuel value.	PERCENTAGES OF TOTAL FOOD. Food materials.	PERCENTAGES OF TOTAL FOOD. NUTRIENTS. Protein.	PERCENTAGES OF TOTAL FOOD. NUTRIENTS. Fat.	PERCENTAGES OF TOTAL FOOD. NUTRIENTS. Carbohydrates.	Fuel value.
FOOD CONSUMED.	Gm.	Gm.	Gm.	Gm.	Cal.	%	%	%	%	%
Animal Food.										
Beef, veal, mutton, -	168	27	15	8	—	8.0	25.4	15.0	2.0	—
Pork, - - -	7	1	2	—	—	.3	1.1	2.2	—	—
Fish, - - -	61	1	—	4	—	3.0	1.1	.5	.9	—
Butter, - - -	33	—	28	—	—	1.6	.3	28.6	—	—
Milk, - - -	820	27	33	41	—	39.4	26.1	33.6	9.6	—
Total animal food,	**1089**	**56**	**78**	**53**	**1175**	**52.3**	**54.0**	**79.9**	**12.5**	**38.1**
Vegetable Food.										
Cereals, - - -	671	41	17	269	—	32.2	39.7	17.6	63.0	—
Sugars and starches,	84	1	1	49	—	4.0	1.0	1.0	11.5	—
Vegetables, - -	158	5	1	30	—	7.6	5.2	1.0	7.0	—
Fruits, - - -	80	1	1	25	—	3.9	.1	.5	6.0	—
Total veg. food, -	**993**	**48**	**20**	**373**	**1910**	**47.7**	**46.0**	**20.1**	**87.5**	**61.9**
Total food, - -	**2082**	**104**	**98**	**426**	**3085**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

No. 321. DIETARY OF A CHEMIST AT MIDDLETOWN, CONN.

This study began with breakfast, January 14, 1900, and continued 3 days, with 9 meals. The subject (J. F. S.) was a chemist, 29 years of age, weighing 145 pounds. The study was made for the purpose of obtaining data on which to base a ration for use in experiments with the subject in the respiration calorimeter. The kinds of food in the diet were the same as would be given him in such experiments, but the amounts consumed were to be determined by his appetite. The composition of the food materials used in this dietary was known with considerable accuracy, so that the figures in the following tables give reliable data concerning the actual nutrients in the food consumed by the subject during this period.

TABLE 27.

Weights of food materials used in dietary No. 321.

Food Materials.	Ref. No.*	Weight. Lbs.	Weight. Oz.	Food Materials.	Ref. No.*	Weight. Lbs.	Weight. Oz.
Animal Food.				*Vegetable Food.*			
Beef,	1	—	12	Bread,	22	2	4.0
Butter,	11	—	7	Parched cereals,	23	—	7.5
Milk,	12	8	12	Ginger snaps,	28	—	7.5
Total animal food,	—	**9**	**15**	Rock candy,	45	—	4.5
				Sugar,	—	—	1.5
				Total veg. food,	—	**3**	**9.0**
				Total food,	—	**13**	**8.0**

* See pp. 126 and 127.

TABLE 28.

Weights and percentages of food materials and nutritive ingredients consumed in dietary study No. 321.

[*Quantities per man per day.*]

Food Materials.	Weights. Food materials.	Weights. Nutrients. Protein.	Weights. Nutrients. Fat.	Weights. Nutrients. Carbohydrates.	Fuel value.	Percentages of Total Food. Food materials.	Percentages. Nutrients. Protein.	Percentages. Nutrients. Fat.	Percentages. Nutrients. Carbohydrates.	Fuel value.
Food Consumed.	Gm.	Gm.	Gm.	Gm.	Cal.	%	%	%	%	%
Animal Food.										
Beef,	113	37	3	—	—	5.5	29.1	1.9	—	—
Butter,	69	3	64	—	—	3.4	2.7	46.1	—	—
Milk,	1322	45	58	64	—	64.7	35.4	42.3	16.1	—
Total animal food,	**1504**	**85**	**125**	**64**	**1775**	**73.6**	**67.2**	**90.3**	**16.1**	**51.9**
Vegetable Food.										
Cereals,	485	41	13	275	—	23.7	32.8	9.7	69.7	—
Sugars, etc.,	56	—	—	56	—	2.7	—	—	14.2	—
Total veg. food,	**541**	**41**	**13**	**331**	**1645**	**26.4**	**32.8**	**9.7**	**83.9**	**48.1**
Total food,	**2045**	**126**	**138**	**395**	**3420**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

No. 322. DIETARY OF A COLLEGE STUDENT AT MIDDLETOWN, CONN.

The subject of this study was the same as in dietary study No. 316, on a preceding page. The study began on January 4, 1900, and continued 3 days, with 9 meals. The conditions and purpose of the study were the same as given for the study of the dietary of a chemist, No. 321.

TABLE 29.

Weights of food materials used in dietary No. 322.

Food Materials.	Ref. No.*	Weight. Lbs.	Weight. Oz.	Food Materials.	Ref. No.*	Weight. Lbs.	Weight. Oz.
Food Consumed. *Animal Food.*				Food Consumed. *Vegetable Food.*			
Beef, - - -	1	1	11.5	Bread, - - -	22	3	6.5
Butter, - - -	11	—	8.0	Graham crackers, -	—	—	3.0
Milk, - - -	12	13	15.5	Parched cereals, -	23	—	8.5
Total animal food, -	—	**16**	**3.0**	Sugar, - - -	—	—	1.0
				Cocoa, - - -	—	—	4.0
				Total veg. food, -	—	**4**	**7.0**
				Total food, - -	—	**20**	**10.0**

* See pp. 126 and 127.

TABLE 30.

Weights and percentages of food materials and nutritive ingredients consumed in dietary study No. 322.

[*Quantities per man per day.*]

Food Materials.	Weights. Food materials.	Weights. Nutrients. Protein.	Weights. Nutrients. Fat.	Weights. Nutrients. Carbohydrates.	Fuel value.	Percentages of Total Food. Food materials.	Percentages. Nutrients. Protein.	Percentages. Nutrients. Fat.	Percentages. Nutrients. Carbohydrates.	Food value.
Food Consumed.	Gm.	Gm.	Gm.	Gm.	Cal.	%	%	%	%	%
Animal Food.										
Beef, - - -	195	63	4	—	—	8.4	39.6	3.2	—	—
Butter, - - -	57	1	49	—	—	2.4	.4	36.2	—	—
Milk, - - -	1584	54	70	76	—	67.8	33.5	51.5	21.7	—
Total animal food,	**1836**	**118**	**123**	**76**	**1940**	**78.6**	**73.5**	**90.9**	**21.7**	**57.9**
Vegetable Food.										
Cereals, - - -	462	41	10	243	—	19.8	25.4	7.4	69.3	—
Sugars, etc., - -	37	1	2	32	—	1.6	1.1	1.7	9.0	—
Total veg. food, -	**499**	**42**	**12**	**275**	**1410**	**21.4**	**26.5**	**9.1**	**78.3**	**42.1**
Total food, - -	**2335**	**160**	**135**	**351**	**3350**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

DIETARY STUDIES IN THE CONNECTICUT HOSPITAL FOR THE INSANE.

By W. O. Atwater.

The importance of more thorough study of the dietaries of public institutions is coming to be generally felt. The number of charitable institutions and the number of persons supported in them at the expense of the community are already large and rapidly increasing. The philanthropy of to-day demands that the welfare of the inmates shall be most carefully considered. The cost to the taxpayer requires the closest economy consistent with their welfare.

In the home, on the farm, in the factory, in commercial establishments, on railroads, in municipal enterprises, indeed, almost everywhere, the results of scientific research are being put to practical use. It would seem that they ought to be capable of being utilized in the dietetic management of public institutions. The probability of their successful application here is rendered all the greater by the fact that during the past few decades a very large amount of scientific inquiry, and that of the highest order, has been devoted to the studies of food and nutrition.

Appreciating these considerations, the New York State Commission in Lunacy has instituted an inquiry into the dietetic management of the hospitals for the insane in that State. This inquiry has been placed under the general direction of the writer. Accounts of the progress of the inquiry have been furnished for publication in the tenth and eleventh annual reports of the Commission.

In the belief that studies of dietaries in the Connecticut Hospital for the Insane would be of interest, advantage was taken of an opportunity offered for such study through the courtesy of Dr. C. W. Page, Superintendent of that institution, and Dr. J. M. Keniston of the medical staff, to whom

especial thanks are also due for important assistance in carrying out the details. Studies were made in two of the buildings in November, 1898, and are here reported. The statistics were gathered by Messrs. A. P. Bryant, H. C. Sherman, and H. E. Wells. The methods of dietary study ordinarily followed by the Station were necessarily modified somewhat in making these two studies. The modifications have been explained on page 125 in the general description of methods given in the preceding article. The tables on pages 145–149 contain the data of these two studies.

I regret that the resources at the disposal of the Station for such investigations have not been sufficient to carry this inquiry further. The results obtained, however, compared with those obtained from the information available from other sources, were such as seemed to warrant a statement to Dr. Page, of which the following is a copy:

MIDDLETOWN, CONN., January 26, 1899.

C. W. Page, M. D., Superintendent, Connecticut Hospital for the Insane, Middletown, Conn.:

MY DEAR SIR:—The results of the dietary studies lately made in your institution are of decided interest. Although they were made in only two of the buildings and continued for but a short time, I see no reason why they should not more or less fairly represent the usage of the establishment as a whole. From the physiological standpoint the diet in the cases studied was ample in quantity; there was, I should say, an excess rather than a deficiency of nutritive ingredients, and the food was in every way wholesome and nutritious. The relative waste was considerably larger at the main building with twenty dining rooms than at the middle building with one large and three very small dining rooms. I think the hospital is to be congratulated upon the success in the feeding of its patients.

Very truly yours,

(Signed) W. O. ATWATER.

I hope there may be opportunity hereafter for further studies such as will warrant more general conclusions. Meanwhile, I think it is safe to say that although the figures given show considerable quantities of waste, these latter are no larger—indeed, they are smaller—than are often found in well managed institutions elsewhere. They indicate that the dietetic management in the Connecticut State Hospital is such as to provide for excellent nourishment at a comparatively low cost. The amounts of food actually eaten per person per day,

as shown by these two studies, are on the whole somewhat larger than the average amounts per person per day eaten by a much larger number of people in New York hospitals whose dietaries were studied. While this fact has less significance than it would have if the studies at the Connecticut Hospital were more numerous, it implies, so far as it goes, that the patients in our institution were liberally fed. The same inference may, I think, be drawn from comparisons with the results of other dietary studies and with dietary standards.

In conclusion, I may say that in my judgment a careful and extensive study of this general subject in the public and charitable institutions of Connecticut is much to be desired.

No. 253. DIETARY AT MIDDLE BUILDING OF THE CONNECTICUT HOSPITAL FOR THE INSANE.

The study began with breakfast, November 3, 1898, and continued 7 days. It was carried on in the part of the Hospital known as the "Middle Building," which accommodates about 400 patients. Most of the patients took their meals in the main dining room. A few, however, who for some reason were not able or were not allowed to eat with these, were served in small dining rooms in the wards. The study shows the amount of food consumed by the patients and the attendants. The patients were of the "quiet demented" sort, who were considered hopelessly insane; but few, if any, of them were violent. The number of persons included in this study is as follows:

	Men.	Women.	Total.
Patients,	184	205	389
Attendants and employés,	13	20	33
Total,	197	225	422

The total number of meals served was thus 8,862, equivalent to 2,954 persons for one day. But little is as yet known concerning the relative amounts of food required by men and women of the insane class, consequently no attempt has been made to calculate the equivalent number of men for one day, the final results being given per person per day.

TABLE 31.

Weights of food materials used in dietary No. 253.*

FOOD MATERIALS.	Ref. No.†	Weight. Lbs.	Weight. Oz.
FOOD PURCHASED. *Animal Food.*			
Beef:			
Roast,	—	90	3
Soup meat,	—	76	—
Steak,	—	205	8
Corned,	—	331	4
Dried,	—	26	8
Pork:			
Ham (boiled),	—	118	3
Salt (fat),	—	18	—
Fish:			
Whitefish,	—	148	8
Cod, salt,	—	50	8
Oysters,	—	103	—
Eggs,	—	53	10
Butter,	—	173	—
Cheese,	—	35	13
Milk,‡	—	1596	8
Total animal food,	—	**3000**	**9**
Vegetable Food.			
Barley, pearled,	—	4	7
Corn meal,	—	43	8
Flour, pastry,	—	40	—
Oatmeal,	—	25	—
Rice,	—	20	10
Biscuit, raised,	24	92	12
Biscuit, soda,	24	72	4
Bread, brown,	—	116	12
Bread, corn,	18	119	4
Bread, ginger,	19	92	—
Bread, graham,	20	151	—
Bread, wheat,	21	2122	—
Crackers, soda,	—	32	4
Spaghetti,	25	70	—
Cake, tea,	26	89	7
Cookies, ginger,	27	51	4
Cookies, sugar,	30	60	—
Doughnuts,	31	76	—
Pie, apple,	—	240	—
Pie, dried peach,	34	121	10
Sugar,	—	226	—
Molasses,	—	4	2
Sirup,	—	50	4
Tapioca,	—	19	8
Beans, dried,	—	89	—
Beets,	—	80	—

FOOD MATERIALS.	Ref. No.†	Weight. Lbs.	Weight. Oz.
FOOD PURCHASED. *Vegetable Food (Con.)*			
Cabbage,	—	207	12
Carrots,	—	7	8
Celery,	—	23	8
Onions,	—	185	8
Potatoes,	—	260	—
Squash,	—	208	—
Sweet potatoes,	—	845	12
Turnips,	—	168	12
Apples,	—	180	4
Prunes, dried,	—	52	—
Raisins,	—	6	7
Total veg. food,	—	**6254**	**7**
Total food,	—	**9255**	—
FOOD WASTED. *Animal Food.*			
Beef:			
Roast,	—	11	7
Steak,	—	32	4
Corned,	—	15	12
Dried,	—	2	4
Pork: ham,	7	11	3
Fish:			
Whitefish,	—	17	8
Cod, creamed,	9	16	—
Soup (dried residue),	10	32	—
Total animal food,	—	**138**	**6**
Vegetable Food.			
Corn meal,	—	7	9
Oatmeal,	—	16	8
Biscuit, soda,	24	4	—
Bread, brown,	—	30	—
Bread, corn,	18	11	12
Bread, ginger,	19	3	—
Bread, graham,	20	8	12
Bread, wheat,	21	241	8
Crackers,	—	1	—
Spaghetti,	25	23	9
Cake, tea,	26	2	4
Cookies, ginger,	27	2	1
Cookies, sugar,	30	1	—
Doughnuts,	31	—	8
Pie, apple,	—	10	7
Pie, dried peach,	34	6	—

* All weights, unless otherwise specified, are of the edible material free from bone, skins, etc.

† See pp. 126 and 127.

‡ Twenty-six pounds of cream was taken from this milk for use elsewhere than in this dietary.

TABLE 31.—*(Continued.)*

Food Materials.	Ref. No.†	Weight. Lbs.	Oz.	Food Materials.	Ref. No.†	Weight. Lbs.	Oz.
FOOD WASTED. *Vegetable Food (Con.)*				FOOD WASTED. *Vegetable Food (Con.)*			
Pudding, bread,	35	19	12	Squash,	—	10	—
Pudding, rice,	39	33	14	Sweet potatoes,	—	131	—
Pudding, tapioca,	41	30	—	Turnips,	—	15	3
Beans, dried,	—	12	9	Apples,	—	7	4
Beets,	—	15	7	Prunes, dried,	—	7	14
Cabbage,	—	11	10	Wet waste,	50	58	5
Celery,	—	7	10	Total veg. food,	—	**774**	**12**
Onions,	—	11	8				
Potatoes,	—	32	14	Total food,	—	**913**	**2**

† See pp. 126 and 127.

TABLE 32.

Weights and percentages of food materials and nutritive ingredients used in dietary study No. 253.

[*Quantities per person per day.*]

Food Materials.	Weights. Food materials.	Nutrients. Protein.	Fat.	Carbohydrates.	Fuel value.	Percentages of Total Food. Food materials.	Nutrients. Protein.	Fat.	Carbohydrates.	Fuel value.
	Gm.	Gm.	Gm.	Gm.	Cal.	%	%	%	%	%
FOOD PURCHASED. *Animal Food.*										
Beef, veal, mutton,	112	19	25	—	—	7.9	19.9	28.3	—	—
Pork,	21	4	6	—	—	1.5	3.9	7.2	—	—
Fish,	46	8	2	1	—	3.3	7.7	1.9	.2	—
Eggs,	8	1	1	—	—	.6	1.2	.9	—	—
Butter,	27	—	23	—	—	1.9	.3	25.3	—	—
Cheese,	6	1	2	—	—	.3	1.5	2.1	—	—
Milk,	241	8	9	12	—	16.9	8.2	10.1	2.8	—
Total animal food,	**461**	**41**	**68**	**13**	**855**	**32.4**	**42.6**	**75.8**	**3.0**	**28.6**
Vegetable Food.										
Cereals,	559	47	20	305	—	39.4	48.5	22.2	71.0	—
Sugars and starches,	46	—	—	43	—	3.2	—	—	10.1	—
Vegetables,	319	8	2	62	—	22.4	8.6	1.8	14.5	—
Fruits,	37	—	—	6	—	2.6	.3	.2	1.4	—
Total veg. food,	**961**	**55**	**22**	**416**	**2135**	**67.6**	**57.4**	**24.2**	**97.0**	**71.4**
Total food,	**1422**	**96**	**90**	**429**	**2990**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
WASTE.										
Animal,	—	4	4	2	60	—	4.4	4.7	.4	2.0
Vegetable,	—	8	2	50	255	—	8.2	2.1	11.6	8.5
Total,	—	**12**	**6**	**52**	**315**	—	**12.6**	**6.8**	**12.0**	**10.5**
FOOD ACTUALLY EATEN.										
Animal,	—	37	64	11	795	—	38.2	71.1	2.6	26.6
Vegetable,	—	47	20	366	1880	—	49.2	22.1	85.4	62.9
Total,	—	**84**	**84**	**377**	**2675**	—	**87.4**	**93.2**	**88.0**	**89.5**

No. 254. DIETARY AT MAIN BUILDING OF THE CONNECTICUT HOSPITAL FOR THE INSANE.

This study was begun with breakfast, November 14, 1898, and continued 7 days. It was carried on in the part of the Hospital known as the "Main Building," which is somewhat larger than the "Middle Building." The method of this study was the same as that of the preceding. The number of persons included in this study is as follows:

	Men.	Women.	Total.
Patients, - - - - - - -	268	285	553
Attendants and employés, - - -	45	52	97
Total, - - - - - - -	313	337	650

The total number of meals served was 13,650, equivalent to 4,550 persons for one day.

Table 33.

Weights of food materials used in dietary No. 254.*

Food Materials.	Ref. No.†	Weight. Lbs.	Weight. Oz.	Food Materials.	Ref. No.†	Weight. Lbs.	Weight. Oz.
Food Purchased. *Animal Food.*				Food Purchased. *Vegetable Food.*			
Beef:				Barley, - - -	—	7	8.0
Beef-tea meat, -	—	147	4.5	Corn meal, - -	—	61	—
Diet steak, - -	—	52	13.5	Rice, - - - -	—	64	12.0
Hamburg steak, -	—	209	8.0	Rolled oats, - -	—	36	—
Liver, - - -	—	20	4.0	Flour, wheat, -	—	80	—
Roast, - - -	—	233	8.0	Bread, brown, -	—	268	9.5
Steak, - - -	—	187	9.0	Bread, corn, - -	18	206	—
Soup meat, - -	—	141	3.5	Bread, graham, -	20	99	8.0
Corned, - -	—	455	8.5	Bread, wheat, -	21	2761	4.0
Dried, - - -	—	34	4.0	Biscuit, soda, - -	24	98	4.0
Pork:				Crackers, soda, -	—	55	—
Ham, - - -	—	305	4.5	Cake, tea, - -	26	124	—
Salt, fat, - -	—	40	1.0	Cookies, molasses, -	29	113	12.0
Fish, etc.:				Cookies, sugar, -	30	86	—
Cod, fresh, - -	—	211	8.0	Doughnuts, - -	32	146	—
Cod, salt, - -	—	62	4.0	Pie, apple, - -	—	653	1.5
Oysters, - -	—	179	4.0	Spaghetti, - -	25	44	9.5
Eggs, - - -	—	220	13.0	Molasses, - -	—	119	12.0
Butter, - - -	—	461	8.0	Sugar, - - -	—	466	—
Cheese, - - -	—	58	4.0	Tapioca, - -	—	31	8.0
Milk, - - -	—	4796	4.0	Beans, - - -	—	265	9.0
				Cabbage, - -	—	277	13.0
Total animal food,	—	7817	1.5	Carrots, - - -	—	29	4.0

* All weights, unless otherwise specified, are of the edible material free from bone, skin, etc.

† See pp. 126 and 127.

TABLE 33.—*(Continued.)*

Food Materials.	Ref. No.*	Weight. Lbs.	Oz.
Food Purchased.			
Vegetable Food (Con.)			
Celery,	—	92	—
Onions,	—	206	13.0
Potatoes,	—	333	9.5
Squash,	—	229	8.0
Sweet potatoes,	—	519	9.5
Turnips,	—	302	—
Peaches, dried,	—	49	8.0
Prunes, dried,	—	68	12.0
Total veg. food,	—	**7896**	**14.5**
Total food,	—	**15714**	—
Food Wasted.			
Animal Food.			
Beef:			
Beef-tea meat,	—	147	4.5
Diet steak,	—	5	4.0
Hamburg steak,	—	22	4.0
Liver,	—	2	—
Roast,	—	47	14.0
Steak,	—	31	4.0
Corned,	—	99	3.0
Dried,	—	3	8.0
Corned-beef hash,	3	39	4.0
"Scramble,"	4	44	4.0
Soup,	5	99	12.0
Soup,	6	125	10.0
Pork: ham, smoked,	—	46	—
Fish, etc., as purchs'd:			
Cod, fresh,	—	83	—
Cod, salt, stewed,	8	50	—
Oysters,	—	13	10.5
Butter,	—	11	14.0
Cheese,	—	1	8.0
Total animal food,	—	**873**	**8.0**

Food Materials.	Ref. No.*	Weight. Lbs.	Oz.
Food Wasted.			
Vegetable Food.			
Corn meal mush,	15	57	8.0
Oatmeal mush,	16	49	10.0
Rice, boiled,	17	54	12.0
Bread, brown,	—	96	15.5
Bread, corn,	18	44	4.0
Bread, graham,	20	6	12.0
Bread, wheat,	21	386	14.0
Biscuit, soda,	24	17	8.0
Crackers, soda,	—	1	3.0
Cake, tea,	26	6	—
Cookies, molasses,	29	2	8.0
Cookies, sugar,	30	3	—
Doughnuts,	32	3	8.0
Griddle cakes,	33	10	4.0
Spaghetti,	25	104	12.0
Pie, apple,	—	38	4.0
Pudding, bread,	36	62	4.0
Pudding, Indian meal,	38	80	8.0
Pudding, rice,	40	51	12.0
Pudding, tapioca,	42	62	8.0
Fish dressing,	44	9	12.0
Beans, cooked,	—	122	—
Cabbage,	—	32	8.0
Celery,	—	66	—
Onions,	—	35	—
Squash,	—	51	4.0
Sweet potatoes,	—	37	12.0
Turnips,	—	26	4.0
Peach sauce,	47	32	12.0
Prune sauce,	48	36	—
Wet waste,	50	94	—
Total veg. food,	—	**1683**	**14.5**
Total food,	—	**2557**	**6.5**

* See pp. 126 and 127.

TABLE 34.

Weights and percentages of food materials and nutritive ingredients used in dietary study No. 254.

[*Quantities per person per day.*]

FOOD MATERIALS.	WEIGHTS.					PERCENTAGES OF TOTAL FOOD.				
	Food materials.	NUTRIENTS.			Fuel value.	Food materials.	NUTRIENTS.			Fuel value.
		Protein.	Fat.	Carbo-hydrates.			Protein.	Fat.	Carbo-hydrates.	
FOOD PURCHASED.	Gm.	Gm.	Gm.	Gm.	Cal.	%	%	%	%	%
Animal Food.										
Beef, veal, mutton, -	148	25	35	—	—	9.4	24.3	26.0	—	—
Pork, lard, etc., -	34	5	15	—	—	2.2	4.7	11.6	—	—
Fish, - - -	45	5	—	1	—	2.9	4.6	.2	.2	—
Eggs, - - -	22	3	2	—	—	1.4	15.1	1.6	—	—
Butter, - - -	46	—	39	—	—	2.9	.4	29.5	—	—
Cheese, - - -	6	2	2	—	—	.4	1.4	1.5	—	—
Milk, - - -	479	16	19	24	—	30.5	2.8	14.5	6.1	—
Total animal food,	**780**	**56**	**112**	**25**	**1375**	**49.7**	**53.3**	**84.9**	**6.3**	**42.1**
Vegetable Food.										
Cereals, - - -	489	39	19	257	—	31.2	37.4	14.2	65.6	—
Sugars and starches,	62	—	—	58	—	3.9	—	—	14.6	—
Vegetables, - -	225	9	1	45	—	14.4	8.9	.9	11.4	—
Fruits, - - -	12	—	—	8	—	.8	.4	—	2.1	—
Total veg. food, -	**788**	**48**	**20**	**368**	**1890**	**50.3**	**46.7**	**15.1**	**93.7**	**57.9**
Total food, - -	**1568**	**104**	**132**	**393**	**3265**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
FOOD WASTED.										
Animal, - - -	—	10	12	4	170	—	9.9	8.8	1.0	5.2
Vegetable, - -	—	10	4	55	305	—	9.3	3.0	13.9	9.3
Total, - -	—	**20**	**16**	**59**	**475**	—	**19.2**	**11.8**	**14.9**	**14.5**
FOOD ACTUALLY EATEN.										
Animal, - - -	—	46	100	21	1205	—	43.4	76.1	5.3	36.9
Vegetable, - -	—	38	16	313	1585	—	37.4	12.1	79.8	48.6
Total, - -	—	**84**	**116**	**334**	**2790**	—	**80.8**	**88.2**	**85.1**	**85.5**

TUBERCULOUS COWS, AND THE USE OF THEIR MILK IN FEEDING CALVES.

By C. S. Phelps.

In October, 1896, the Station made arrangements with the State Cattle Commissioners by which four condemned Devon cows were taken for experiment. The herd from which these animals came was first tested with tuberculin in March, 1896, but these particular animals failed to respond. In October, 1896, the herd was again tested with tuberculin, and the four cows, which failed to respond in the earlier test, responded, and were shortly after taken to the Station. These tests were made under the supervision of the State Cattle Commissioners.

The following table gives the temperatures in the two tests made before the cows were taken for experiment. The official numbers for the cows used in these tests have been retained by the Station.

TABLE 35.

*Tuberculin tests made with cows prior to their arrival at the Station.**

Number of Cow.	Before Injection.		After Injection.				
	8 P. M.	10 P. M.	6 A. M.	8 A. M.	10 A. M.	12 M.	2 P. M.
Test made March 14–15, 1896.							
1337, - - - - -	102.2	102.8	102.3	102.6	103.0	102.4	102.4
1341, - - - - -	101.1	101.3	101.6	102.2	102.2	102.4	102.0
1343, - - - - -	101.0	101.6	101.8	101.8	102.1	102.1	102.2
1344, - - - - -	101.0	101.5	100.7	101.6	101.4	102.0	101.4
Test made October 26–27, 1896.							
1337, - - - - -	101.3	101.4	100.6	101.6	103.0	**104.4**	**104.8**
1341, - - - - -	101.6	101.4	100.8	101.7	102.4	**104.4**	**105.6**
1343, - - - - -	102.0	101.7	99.6	101.6	102.8	**104.4**	**105.0**
1344, - - - - -	101.8	101.1	102.0	102.0	**105.0**	**105.8**	**105.6**

* Through the courtesy of the former Secretary of the State Cattle Commission we are able to publish the temperatures obtained in the tuberculin tests made prior to the arrival of the cows at the Station. These tests were made by Dr. L. J. Storrs.

Care of the cows, and tuberculin tests after they were taken in charge by the Station.—When the cows were brought to the Station they were placed in a high, light, and airy stable, affording about 1,500 cubic feet of air space per cow, although later several calves occupied the same stables with the cows. The Station barn is located about eighty rods from the College barn, and the tuberculous animals have been kept separate from any other cattle. Adjoining the stable is a yard about one-half acre in area, where the animals can exercise. In mild weather they have occupied the yard most of the day. No special treatment for the disease has been attempted, but good care and feed have been afforded at all times. Plans were made whereby the animals could be subjected to the tuberculin test from time to time. These tests were, in most cases, made by the College veterinarian.

The four cows have been under the care and observation of the Station for three and one-half years at the time this report closes (May, 1900). Accounts of the general health of the animals, and the results of tests on the use of their milk in feeding both their own offspring and calves from healthy cows, have been given in the last two reports of the Station. Up to September, 1897, these tests were made by Dr. George A. Waterman. The test in September, 1897, was made by Dr. L. J. Storrs, as the College was temporarily without a veterinarian. Beginning with December, 1897, the tuberculin tests, and three physical examinations, have been made by Dr. N. S. Mayo. Since that time the tuberculin tests of the cows have been made less frequently than for the first year that the animals were at the Station. In the tests made by Dr. Waterman only two temperatures were taken before the tuberculin was injected, while in the tests made by Dr. Mayo temperatures were taken every two or three hours for a period of twelve to fifteen hours before injection. In the tables only the maximum and the average temperatures before injection are given. A rise of two or more degrees above the maximum temperature before injection, occurring within twenty-four hours after injection, is considered a response to the tests. The tuberculin tests made since January 1, 1897, are shown in the following table. The temperatures which indicate a response to the test are printed in bold-faced type.

TABLE 36.

Tuberculin tests of tuberculous cows, and of calves which were fed their milk.

Date of Test, Number and Age of Animal.	Before Injection.*		After Injection.							
			6 A.M.	8 A.M.	10 A.M.	12 M.	2 P.M.	4 P.M.	6 P.M.	8 P.M.
Jan. 26–27, 1897.	5 P.M.	9 P.M.								
1337, 4 yrs., - -	101.0	101.2	101.5	102.1	**104.0**	**105.2**	**106.1**	—	**104.8**	—
1341, 6 yrs., - -	102.2	101.5	102.1	102.5	103.6	102.6	103.2	**104.9**	**106.1**	—
1343, 6 yrs., - -	100.9	100.3	101.4	102.0	102.9	**105.1**	**106.2**	—	**105.0**	—
1344, 6½ yrs., -	100.6	100.1	101.2	101.6	103.0	**105.0**	**105.9**	—	**105.6**	—
A (calf), 1 mo., -	102.0	102.0	101.5	101.1	101.4	101.6	101.6	—	102.2	—
Mar. 3–4.	4 P.M.	9 P.M.								
B (calf), ½ mo., -	102.7	103.4	102.1	102.6	102.2	101.5	101.7	—	—	—
Mar. 29–30.	5 P.M.	9 P.M.								
A (calf), 3 mos., -	102.4	102.6	102.4	102.0	101.7	101.9	102.4	—	—	—
April 26–27.	5 P.M.	9 P.M.								
1337, 4½ yrs., -	103.7	102.0	102.4	102.2	102.0	102.2	102.0	—	—	—
1341, 6½ yrs., -	102.8	101.5	102.6	103.7	**105.2**	**106.0**	**105.8**	—	—	—
1343, 6½ yrs., -	102.0	101.6	102.0	102.0	102.2	102.0	101.8	—	—	—
1344, 7 yrs., - -	101.6	101.0	102.5	103.4	**103.8**	**103.8**	102.8	—	—	—
July 30–31.	5 P.M.	11 P.M.								
1337, 4½ yrs., -	101.8	101.3	102.2	102.0	102.2	102.1	102.2	101.3	102.4	102.1
1341, 6½ yrs., -	101.6	101.0	102.5	102.8	101.9	101.8	101.5	101.2	101.3	101.0
1343, 6½ yrs., -	101.8	101.0	102.8	102.7	102.1	102.2	102.0	101.8	101.4	101.4
1344, 7 yrs., - -	101.1	100.6	102.1	102.4	101.7	102.0	102.0	102.0	102.0	101.0
A (calf), 7 mos., -	102.5	101.8	101.8	101.8	101.4	102.0	101.8	—	—	—
B (calf), 5 mos., -	101.8	101.9	101.2	101.4	101.6	101.6	101.9	—	—	—
C (calf), 3 mos., -	103.0	102.0	101.8	101.5	101.7	101.8	102.4	—	—	—
Sept. 27–28.	8 P.M.	10 P.M.								
1337, 5 yrs., - -	—	101.8	102.0	102.1	101.9	101.6	101.6	—	—	—
1341, 7 yrs., - -	—	101.5	101.3	101.2	101.5	102.0	101.8	—	—	—
1343, 7 yrs., - -	—	101.7	101.5	101.6	101.5	101.3	101.5	—	—	—
1344, 7½ yrs., -	—	101.0	101.1	101.4	101.2	101.2	101.1	—	—	—
A (calf), 9 mos., -	102.6	101.6	101.6	101.4	101.7	101.8	102.0	—	—	—
B (calf), 7 mos., -	102.3	101.7	101.7	101.3	101.0	101.2	101.5	—	—	—
C (calf), 6 mos., -	102.4	101.6	101.8	101.4	101.7	101.8	101.8	—	—	—
Dec. 17–18.	Maximum.	Average.†								
1337, 5 yrs., - -	102.8	101.6	101.3	101.7	102.9	102.9	102.6	102.5	103.0	103.5
1341, 7 yrs., - -	102.2	101.3	101.2	102.0	102.3	103.0	102.2	102.6	102.1	101.5
1343, 7 yrs., - -	102.2	101.5	101.1	102.0	101.9	102.4	102.0	101.8	101.0	101.8
1344, 7½ yrs., -	102.3	101.0	101.5	102.2	**104.4**	**106.4**	**107.0**	**105.7**	**104.4**	102.8
A (calf), 1 yr., -	101.8	101.1	100.8	101.8	101.6	101.6	100.9	102.2	101.8	101.0
B (calf), 10 mos., -	101.8	101.3	101.0	101.2	101.0	101.2	101.9	101.7	102.2	100.8
C (calf), 9 mos., -	102.2	101.4	101.0	101.5	101.2	101.4	101.7	101.7	102.2	101.4
D (calf), 1 mo., -	102.6	102.1	102.0	101.7	101.2	102.0	101.8	102.0	102.0	102.0

* The tuberculin was injected between 9 and 11 P. M. of the first day.

† Average of temperature taken once in two or once in three hours for 12 to 15 hours before injection.

TABLE 36.—*(Continued.)*

Date of Test, Number and Age of Animal.	Before Injection.*		After Injection.							
	Maximum.	Average.†	6 A.M.	8 A.M.	10 A.M.	12 M.	2 P.M.	4 P.M.	6 P.M.	8 P.M.
April 11–12, 1898.										
1337, 5½ yrs.,	101.8	101.3	101.8	102.6	102.3	102.2	101.8	101.8	101.9	102.0
1341, 7½ yrs.,	101.8	101.3	102.0	102.6	102.4	102.6	101.9	102.0	101.8	101.6
1343, 7½ yrs.,	102.1	101.5	102.3	**104.0**	**104.2**	**104.5**	**104.0**	102.5	101.9	102.0
1344, 8 yrs.,	101.2	100.8	101.7	102.5	102.7	102.8	102.7	103.0	103.2	103.0
A, 16 mos.,	102.2	101.4	101.6	101.8	101.6	102.0	101.8	101.3	102.0	102.0
B, 14 mos.,	101.9	100.9	100.5	101.0	100.6	100.6	100.8	100.5	101.4	101.4
D, 4 mos.,	102.3	101.8	102.3	101.8	101.7	101.7	102.0	102.7	102.6	102.6
Dec. 22–23.										
1337, 6 yrs.,	103.0	101.9	101.2	102.2	102.9	102.0	101.9	101.3	101.3	—
1341, 8 yrs.,	103.0	101.7	102.6	103.8	103.9	100.0	100.8	102.1	101.9	—
1343, 8 yrs.,	103.0	102.1	104.2	103.8	103.8	101.5	102.1	102.3	101.7	—
1344, 8½ yrs.,	102.4	101.4	101.6	102.0	102.4	101.4	100.8	101.1	101.3	—
A, 2 yrs.,	102.5	101.5	101.4	101.7	102.2	102.6	103.1	102.5	102.5	—
B, 22 mos.,	102.2	101.7	**104.4**	**106.2**	**106.3**	**104.9**	**106.0**	**105.3**	**105.0**	—
C, 21 mos.,	102.2	100.6	102.1	102.3	101.4	101.6	102.9	101.6	—	—
D, 13 mos.,	102.2	101.9	101.6	102.2	101.8	102.0	101.7	101.9	101.9	—
E, 4 mos.,	102.8	102.0	101.5	101.7	101.4	102.1	101.7	101.8	101.6	—
F, 4 mos.,	103.3	102.1	102.0	102.0	101.6	102.5	101.6	101.6	102.7	—
G, 4 mos.,	103.0	102.6	101.4	101.8	100.8	102.2	103.1	102.9	102.2	—
H, 3 mos.,	102.4	102.0	102.6	101.4	101.5	101.2	101.4	101.4	101.8	—
April 11–12, 1899.										
A, 2⅓ yrs.,	102.4	101.9	102.0	101.4	100.8	100.4	101.9	101.3	—	—
June 2–3.										
1337, 6½ yrs.,	102.2	101.4	101.1	101.8	102.3	102.0	101.7	102.1	—	—
1341, 8½ yrs.,	103.0	102.0	101.2	100.8	102.8	102.6	102.8	102.0	—	—
1343, 8½ yrs.,	101.8	101.4	**105.4**	**104.7**	**103.7**	**104.7**	103.5	100.5	—	—
1344, 9 yrs.,	102.0	101.4	102.2	101.7	102.5	102.8	103.1	103.0	—	—
D, 18 mos.,	102.1	101.8	101.7	100.8	100.4	101.2	101.5	101.7	—	—
E, 10 mos.,	103.0	101.8	101.3	101.2	101.7	101.2	101.5	101.5	—	—
F, 10 mos.,	103.2	101.9	101.5	101.4	101.6	101.8	102.2	102.6	—	—
G, 9 mos.,	102.8	102.2	101.2	101.7	101.2	101.5	101.2	101.7	—	—
H, 9 mos.,	105.9	105.1	103.4	103.6	104.5	104.7	105.4	105.4	—	—
I, 3 mos.,	102.6	102.0	101.4	102.8	103.6	103.8	104.5	**104.6**	—	—
Dec. 1–2.										
1337, 7 yrs.,	100.6	100.4	101.2	101.4	102.2	102.4	102.6	101.8	101.6	—
1341, 9 yrs.,	103.8	102.4	104.0	103.4	102.8	**106.2**	101.8	102.0	102.7	—
1343, 9 yrs.,	103.8	102.8	105.6	105.6	105.4	104.8	103.6	103.0	103.4	—
1344, 9½ yrs.,	102.0	100.9	102.4	102.2	102.4	103.2	100.0	100.0	103.0	—
E, 16 mos.,	102.9	102.2	103.2	104.4	104.8	**106.1**	**106.0**	**105.2**	**105.2**	—
F, 16 mos.,	103.0	102.2	102.2	102.4	101.6	101.6	102.0	101.0	101.4	—
G, 15 mos.,	103.2	102.8	104.2	**105.4**	**106.0**	**105.2**	105.0	103.8	103.8	—
H, 15 mos.,	102.2	101.5	103.0	103.8	**107.2**	**106.0**	**105.4**	**105.4**	**104.8**	—
I, 9 mos.,	102.0	101.8	102.6	103.2	103.4	**104.0**	**104.2**	**104.2**	103.0	—

* The tuberculin was injected between 9 and 11 P. M. of the first day.

† Average of temperature taken once in two or once in three hours for 12 to 15 hours before injection.

TABLE 36.—*(Continued.)*

DATE OF TEST, NUMBER AND AGE OF ANIMAL.	BEFORE INJECTION.*		AFTER INJECTION.						
			6 A.M.	8 A.M.	10 A.M.	12 M.	2 P.M.	4 P.M.	6 P.M.
Mar. 19–20, 1900.	Maximum.	Average.†							
1337, 7½ yrs., -	101.7	101.3	101.6	101.2	101.6	102.2	102.3	100.8	101.2
1341, 9½ yrs., -	102.6	101.8	102.9	103.9	103.8	104.2	100.4	100.9	102.3
1343, 9½ yrs., -	102.1	101.2	102.1	101.6	103.7	103.5	101.8	102.0	102.1
1344, 10 yrs., -	101.8	100.6	101.2	101.7	101.9	101.9	102.0	102.0	101.7
F, 19 mos., - -	102.2	101.4	102.1	102.6	**104.3**	**105.2**	103.7	**104.8**	**105.3**
H, 18 mos., - -	102.3	101.6	103.0	103.2	103.4	104.0	102.2	101.8	102.7
K, 3 mos., - -	102.5	102.2	104.2	105.0	**106.2**	**107.2**	**106.3**	**106.7**	**106.3**

* The tuberculin was injected between 9 and 11 P. M. of the first day.

† Average of temperature taken once in two or once in three hours for 12 to 15 hours before injection.

HISTORY AND PHYSICAL CONDITION OF THE COWS FROM FEBRUARY, 1899, TO MAY, 1900.

Cow No. 1337.—This cow was in good condition of flesh during the late winter and throughout the spring of 1899. She continued to suckle her calf (H), which had been dropped September 15, 1898, throughout the spring and summer of 1899. The cow had a smooth, sleek coat, seemed bright and active, and showed no tendency to cough. The calf was prevented from sucking its dam after reaching the age of one year, September 15, 1899. At this time the cow was beginning to show indications of drying off preparatory to calving, and milking her was discontinued the latter part of September. This cow produced a vigorous calf, December 2, 1899, which appeared to be full sized and well developed. The calf was attacked by scours soon after birth, and died December 4. The cow continued in a vigorous condition of health throughout the winter, having a sleek coat, remaining in a good state of flesh, and producing from 16 to 20 pounds of milk per day. In May, 1900, she appeared active and vigorous, with the exception of a slight cough which developed during the latter part of the winter or in the early spring. Cow No. 1337 was subjected to the tuberculin test, June 2–3, and December 1–2, 1899, and March 19–20, 1900, but did not respond to any of the tests. This cow has not responded since January, 1897, a period of three and one-third years.

Cow No. 1341.—This cow remained in a fair condition of flesh during the late winter and throughout the spring of 1899. She continued to give a good flow of milk until the latter part of July of that year. At that time the animal was attacked by scours, showed loss of appetite, and began to decline in flesh quite rapidly. She was isolated from the rest of the herd in a small open shed, and after about a week ceased to give milk entirely for seven or eight days. Soon after this her appetite began to improve and she ate dry fodders quite freely. Milking was then resumed, and the milk flow increased greatly in quantity for the next three weeks. This cow improved somewhat in condition of flesh during August and September, 1899, and remained in a fair state of health throughout the fall and early winter. She was dried off, preparatory to calving, late in December. This cow has had a somewhat irregular tendency to a looseness of the bowels, but showed no further signs of scours during the fall of 1899. Up to this time she had not coughed noticeably since coming to the Station in November, 1896. Cow No. 1341 was dry from late in December, 1899, till February 11, 1900, at which time she dropped a vigorous calf. The calf appeared fully developed, but it was attacked by scours a few days after birth and died February 15. After calving the cow was rather thin in flesh, although she gave a good flow of milk, during March producing from 25 to 30 pounds per day. During the spring of 1900 this cow seemed thin in flesh, had a rough coat, a dull, sunken eye, and was rather hollow and sunken at the flanks. She has coughed considerably throughout the winter and spring, and if exercised vigorously will cough severely. This cow is evidently "running down," although she gives a good flow of milk at the present time (May, 1900). Cow No. 1341 was tested with tuberculin June 2–3, 1899, but did not respond, and again December 1–2, 1899, when she responded. March 19–20, 1900, she was tested again, but did not respond.

Cow No. 1343.—This cow remained in a good state of flesh during the late winter and throughout the spring of 1899. She has always shown a beefy tendency, appearing rather fat. During the latter part of the winter of 1898 and 1899 she did not appear as fleshy as formerly, but yet was in good order. She continued to produce a fair flow of milk during the summer and early fall of 1899, and remained in a fair state of

flesh, although not as fat as during the summer of 1898. Up to the fall of 1899 she had shown more of a tendency to cough than any of the other cows. This was especially noticeable after feeding dry feeds or when the animal was made to exercise violently. This cow went dry about the middle of November, and calved December 23, 1899, producing a strong, vigorous heifer calf. The calf had a mild attack of scours a few days after birth, but recovered within a short time. The cow lost flesh quite rapidly after calving, although she has continued to produce a good flow of milk. She gave from 16 to 22 pounds of milk for the first three months after calving. At the present time (May, 1900,) she is rather thin, her ribs protruding quite plainly. Cow No. 1343 coughs more than any of the other cows, and her coughing has increased in frequency during the past six months. This cow was tested with tuberculin June 2–3, 1899, and responded to the test. She was again tested December 1–2, 1899, and March 19–20, 1900, at which times she gave no response.

Cow No. 1344.—This cow remained farrow, after coming to the Station in the fall of 1896, until the fall of 1899. During this time she continued to produce a good flow of milk. In April and May, 1899, she was giving from 8 to 11 pounds per day. During the spring and summer of 1899 she was in a fair state of flesh and appeared to be quite vigorous in health. She was dried off, preparatory to calving, about September 1, 1899. This cow manifested a lameness in the stifle joint of the right rear leg some time during the summer of 1899, and although she became somewhat lame it seemed to give her comparatively little trouble. This cow dropped a bull calf October 15, 1899. The calf appeared rather weak at birth and refused to suckle its dam, and was probably premature by about a month. The calf died October 22, 1899. The cow began to produce a liberal flow of milk shortly after calving, and during the latter half of November was giving from 25 to 30 pounds per day. She kept up a good flow of milk throughout the winter, producing from 18 to 20 pounds per day near the end of March, 1900. Previous to the winter of 1899 and 1900 this cow had been in a fair state of flesh, with a tendency to remain rather fat, although during the summer of 1899 she was not as fleshy as in 1898. During the past six months she has lost

flesh, and at the present time (May, 1900,) seems quite thin and shows the position of her ribs plainly. Previous to the fall of 1899, cow No. 1344 was not noticed to have any cough, but during the past winter she has coughed quite vigorously. The lame leg has been quite badly swollen about the stifle joint, and this lameness has caused her considerable inconvenience in moving about. She was, however, less lame after warm weather came, and she was able to exercise freely in the yard. This cow was tested with tuberculin June 2–3, and December 1–2, 1899, and again March 19–20, 1900, but did not respond to any of these tests.

PHYSICAL EXAMINATIONS.

On May 8, 1898, and February 7, 1899, Prof. N. S. Mayo, the College Veterinarian, made physical examinations of the animals. The report of these examinations were given in the article on the subject in the Report of the Station for 1898. They are repeated here for comparison with the report of the examination made by the same veterinarian, May 26, 1900. These reports are as follows:

Report of the Veterinarian, May 8, 1898.—It is a fact well recognized that bovine tuberculosis, unless well advanced, is one of the most difficult diseases to diagnose upon a physical examination.

Of the seven animals examined four are the Devon cows that have been tested and found to respond at one time or another, three (A, B, and D) are young bulls that have been fed with the milk of the cows. The calves have not reacted to the tuberculin test, and a careful physical examination fails to reveal any indications that they have tuberculosis.

Of the four cows that have responded to the test, No. 1337 presents no symptoms of tuberculosis. She is in good flesh and looks well. Her temperature was 102.2° F., respirations full and at the rate of twelve per minute.

Cow No. 1341 is thinner in flesh than any of the others, and seems to be affected with a slight but chronic looseness of the bowels. Her temperature was 102° F., and respirations twelve per minute.

Cow No. 1343 is rather fat. She is troubled with a chronic cough, and auscultation indicates that the anterior (cephalic) lobes of the lungs, especially the right, are tuberculous. Her temperature was 102.6° F., and respirations are twenty-two per minute. Cows Nos. 1337, 1341, and 1343 are pregnant.

Cow No. 1344 is in good flesh. Temperature 101.8° F., and respirations fifteen per minute. Nothing abnormal could be detected upon a physical examination. No enlarged glands could be detected in any of the animals examined. Of the four cows that have at some time responded to the test, Nos. 1337 and 1344 show no symptoms of the disease having developed. In No. 1341 the chronic looseness of the bowels may be considered as a suspicious symptom of a tubercular affection of the digestive tract. In No. 1343 the physical symptoms indicate tuberculosis of the lungs.

It must be remembered that all of these animals have had good care and attention, and have not been exposed to conditions or circumstances that would cause the disease to develop.

Report of the Veterinarian, February 7, 1899.—Of the four Devon cows examined, No. 1337 does not seem to be in as thrifty condition as she ought to be, considering her care and feed. No. 1341 is not in as thrifty condition as No. 1337, and would probably be condemned as tuberculous on a physical examination. Nos. 1343 and 1344 are in excellent condition, physically, both being rather fat, and are looking well. The only evidence of disease is found in No. 1343, her respirations not being as full and deep as they should be normally. No cough was noted in any of the animals.

Report of the Veterinarian, May 26, 1900.—Cow No. 1337. In excellent physical condition as far as could be determined; good flesh, coat smooth and of good color, respirations sixteen per minute. I was unable to detect any abnormal sounds or absence of sounds in the lungs upon auscultation. This cow is evidently well along in pregnancy.

Cow No. 1341. Thin in flesh and does not look in a thrifty condition. Coat is rough and has not shed well. A part of her physical condition may be attributed to her having been in milk for some time. This cow's lungs appear to be slightly affected. Respirations, twenty-two per minute.

Cow No. 1343. Rather thin in flesh. Coat looks some better than No. 1341, but No. 1343 coughs quite badly, and auscultation reveals considerable areas of solidification in both lungs. Respirations, thirty-six per minute.

Cow No. 1344. Very thin in flesh, and her general physical condition is not good. She is suffering from severe lameness in the right hind leg, which appears to be due to a tubercular affection of the stifle joint. A considerable portion of this cow's poor condition must be attributed to her lameness. Respirations, twenty per minute.

N. S. MAYO, D. V. S., *College Veterinarian.*

FEEDING CALVES WITH THE MILK OF TUBERCULOUS COWS.

A large part of the time during the past three and one-half years the milk of the four tuberculous cows has been fed to calves. In some instances the milk has been fed until the calf was a year or more in age. In a few cases the calves were allowed to suckle their dams, while in others they were fed the milk from pails. In most of these experiments the calves have been kept in the same stable with the cows, and, of course, there was considerable likeliness that the disease might be contracted from other sources than the milk. One object of the experiment was to test the relative danger in keeping calves associated with the cows. In some later experiments calves are being fed the milk of these cows while being quaranteened from them.

During the first two years that the cows were at the Station four calves were kept in the stable with them a large part of the time, and were fed the milk of the diseased cows, but in no case did the calves show any sign of the disease as far as could be detected by the tuberculin test or by physical symptoms. The following is a brief history of the feeding tests which have been made during the three and one-half years that the cows have been at the Station.

Feeding Calf A with the milk of Cows 1344 and 1341.—This calf was dropped December 25, 1896, by a vigorous grade cow in the college herd. The calf was fed the milk of cow No. 1344 from January 7 to March 28, 1897. It was tested with tuberculin January 26–27, and again March 29–30, 1897, but gave no response to either of the tests. At that time the supply of milk from cow No. 1344 was less than the calf seemed to need, and it was fed the milk of cow No. 1341. Calf A was fed the milk of this cow from April 1, 1897, to July 9, 1898. In May, when about a year and a half old, it was castrated, and was sent to pasture early in July following. At the time this steer went to pasture it was a vigorous animal weighing about 500 pounds. Early in November steer A was returned to the same stable with the tuberculous cows, and during the following winter was fed a suitable ration for fattening. The animal was sold for beef in April, 1899. Tuberculin tests of this animal were made January 26–27, March 29–30, July 30–31, September 27–28, December 17–18, 1897, and April 11–12, and December 22–23, 1898, and again just before being sold for beef, April 11–12, 1899. From this record it may be seen that this animal was fed the milk of two of the tuberculous cows for about a year and a half, was then at pasture for about four months, then it was again kept in the same stall with the tuberculous cows for another period of five months. The animal remained healthy, as far as was indicated by the tuberculin test or by physical examination, up to the time of slaughter, when nearly two years and four months old.

Feeding Calf B with the milk of Cow 1343.—This calf was dropped by a vigorous Jersey cow in the college herd, February 20, 1897, and was ten days old when the feeding period began. When about two weeks old it was tested with tuberculin, and gave no response. From March 1, 1897, to early

in July, 1898, calf B was fed the milk of cow No. 1343. This calf was not a vigorous eater, and at times refused single feeds of milk. The calf seemed healthy, and ate hay readily. When a year old the animal was thought to be rather small for its age, but this may have been due to the fact that it had always refused grain feeds. This animal was castrated in May, 1898, and was sent to pasture with steer A in the early part of July. It was returned to the same stable with the cows early in November, and started upon a heavy grain ration with a view to fattening for beef. December 22–23, this steer gave a marked response to the tuberculin test (see temperature, Table 36, page 153). In addition to the marked rise in temperature, the steer showed physical symptoms by a roughness of the coat, shivering, and twitching of the muscles. Steer B was killed and carefully examined by the College Veterinarian, Dr. Mayo, December 30, 1898. The only trace of the disease found was a few small tubercles in one of the pharyngeal glands of the throat. The disease was, with little doubt, of recent origin. While, of course, there is no proof as to how this animal contracted the disease, it seems quite probable that the germs may have entered the system in the breath after the animal was returned to the stable early in November, 1898.

Feeding Calf C with the milk of Cow 1337.—This was a heifer calf, dropped by cow No. 1337, April 5, 1897. The calf was allowed to suckle its dam until about six months old. About October 1 the calf was weaned, but was fed the milk of its dam until January, 1898. It was then gradually put upon a skim-milk diet, and was placed in the college herd with the intention of raising the calf for dairy purposes. The animal was tested with tuberculin July 30–31, September 27–28, and December 17–18, 1897, and again December 22–23, 1898. The heifer produced her first calf December 5, 1899, and has continued to give a fair flow of milk. She was tested with tuberculin June 2–3 and December 7–8, 1899, and April 25–26, 1900, but gave no response.

Feeding Calf D with the milk of Cow 1344.—This was a bull calf, dropped by a vigorous grade cow, November 29, 1897. It was fed the milk of cow No. 1344 from early in December, 1897, till February, 1899, after which it was given a grain and

hay ration entirely. From the time of birth until June, 1899, this animal was kept in the same stable and yard with the cows. It was then sold to a farmer living near the Station, who was informed of the history of the animal, and has been used since that time for breeding purposes. This animal (D) was tested with tuberculin December 17–18, 1897, and April 11–12, and December 22–23, 1898, and June 2–3, 1899, but in no case did it give any response to the test. When sold it it was a strong, vigorous animal, and seemed large for its age.

From these records it will be seen that the milk of the four cows was fed to four calves for periods varying from three months to a year and four months, and that in no case was there any sign of the disease during the feeding period. One animal (B) did respond to the tuberculin test nearly six months after the feeding period with the milk was ended, but from the mild form in which the disease then existed it would seem doubtful if the disease was contracted from the milk. These tests point to the conclusion that the milk of tuberculous cows, in the early stages of the disease, is not very likely to transmit the disease when fed to healthy calves.

As will be seen from the records of the history and conditions of the animals, cows Nos. 1337, 1341, and 1343 produced calves in August and September, 1898. It was decided to feed several of these calves upon the milk of their dams. These feeding tests were continued for about a year.

Feeding Calves E and F with the milk of Cow 1341.—Calf E was a large heifer calf dropped by cow No. 1341, August 11, 1898; and calf F was a bull calf dropped by a grade cow in the college herd about the same date. The dam of calf F was supposed to be healthy, but three months after the birth of the calf the cow developed a severe case of tuberculosis.* The

* This cow was tested with tuberculin December 30-31, 1897, but gave no response to the test. She calved August 27, 1898, and appeared in a healthy, vigorous condition until the herd was placed in winter quarters early in November. Soon after, she began to refuse silage, and dropped off rapidly in milk flow, but manifested no serious symptoms until about ten days after she began to refuse silage. At that time the cow began to scour badly, and was placed in a box stall away from the rest of the herd. For the next ten days she ran down in flesh rapidly, so that it was thought wise to destroy her. A post-mortem examination showed a severe case of tuberculosis, the tubercular lesions being present in the liver, the spleen, and the lungs. Some of the lesions were encysted in such a way as to indicate that the disease was one of long standing, and it is probable that the tuberculin test which was made eleven months previous to the time of killing the cow failed to cause a response, owing to the advanced condition of the disease, or the failure may have been due to a poor lot of tuberculin. The cow showed no outward appearance of the disease, and remained in good condition of flesh until she began to refuse her feed early in November, 1898.

calf appeared healthy and vigorous at birth, and continued so until more than a year and a half old. The plan of the test with these two calves was to pasteurize one-half of the milk of cow No. 1341 and feed it to its offspring, and to feed the balance of the milk in its normal condition to calf F. This calf was chosen for the purpose, because it was supposed that its dam was free from tuberculosis, as she did not respond to the tuberculin test made about seven months prior to the birth of the calf.

Both of these calves have been kept in a room separate from the tuberculous cows, although in the same barn with them. The calves were in the second story of the barn, while the cows were stabled in the basement underneath. The portion of the milk of cow No. 1341 which was fed to calf E was heated to a temperature of from 170° to 175° F., and diluted with cold water before feeding. The balance of the milk of the same cow, in a normal condition, was fed to calf F as soon as possible after milking. Both calves had a small quantity of bran added to the milk after they were about two months old. The feeding tests of these two calves continued from August, 1898, till June 5, 1899. Both calves were tested with tuberculin when about four months old, December 22–23, 1898, and again June 2–3, 1899, when nearly ten months old. In neither of these cases did they show any response to the test.

It was planned that the feeding tests of these two calves should continue for about two weeks longer, or until the animals could be sent to pasture; but by a misunderstanding on the part of the attendant the milk was not pasteurized for calf E, and both animals were fed the normal milk of cow No. 1341 from June 5 to 24, or for a period of nearly three weeks. Both calf E and calf F were brought from the pasture November 13, and were placed in the same stable with the tuberculous cows. They were again subjected to the tuberculin test December 1–2, 1899. Calf E (the offspring of cow No. 1341) responded to the test, giving a maximum temperature of 106°, while calf F showed no rise of temperature. Calf F was kept in the same stable with the cows until April, 1899, and in March, 1899, when nineteen months old, it also responded to the tuberculin test.

The history of these two calves and the peculiarity of the feeding tests are such as require more than passing notice. Calf F was the offspring of a cow which, within three months after birth of this calf, developed a severe case of tuberculosis. To the best of our knowledge also the dam of calf E was a pronounced case of tuberculosis. Dr. Mayo, in a report of the physical condition of the cows, February 7, 1899, says: "Cow No. 1341 . . . would probably be condemned as tuberculous on physical examination." Calf F was fed the normal milk of a tuberculous cow (No. 1341) for about ten months; was then at pasture for about five months, and was in the stable with the tuberculous cows for about four months more before it responded to the tuberculin test. Calf E was fed pasteurized milk from cow No. 1341 for nearly ten months, then normal milk from the same cow for about three weeks, then was at pasture nearly five months, and responded to the tuberculin test within three weeks of the time she was returned to the stable. The result of these tests seem to show that there were marked differences in the two calves in their power to resist the germs of tuberculosis. It would seem either that calf E must have contracted the disease within the three weeks in June, 1899, while it was being fed the normal milk of its dam, or else that the quarantine between the calves and the cows in the same barn was not effectual. On the other hand calf F, the offspring of another badly diseased cow, resisted the germs from the normal milk of cow No. 1341 for a period of over ten months, and also failed to contract the disease from association with the cows until a period of about a year had elapsed (omitting the time at pasture). The post-mortem examination of calf E was made by the College Veterinarian, February 12, 1900. The only trace of the disease discovered was in the liver, in which one tubercle, which was somewhat cheesy and about the size of a large walnut, was found in one of the smaller lobes. Calf F was sold in the Brighton market, under Government inspection, in April, 1900, and was passed as a slightly diseased animal.

Feeding Calf G with the milk of Cow 1343.—This was a small heifer calf, dropped by cow No. 1343, August 28, 1898. It was small at birth and appeared rather puny until a year or more old. It was fed the milk of its dam from the time of

birth until June 24, 1899, although it did not eat well and consumed only small quantities of the milk. This calf seemed to lack vigor, and remained thin in flesh until after it was sent to pasture late in June, 1899. This animal was at pasture with calves F and E from June 24 until November 13, 1899. It gave no response to tuberculin tests made December 22–23, 1898, and on June 2–3, 1899, but did respond to a test made December 1–2, about three weeks after the calf was returned to the stable from the pasture. The post-mortem examination made February 12, 1900, showed the following organs affected: left lung, cordal lobe, one tubercle about the size of a small walnut; in liver, several tuberculous bunches about the size of large peas; one lymphatic gland of the small intestines was tuberculous, being much enlarged, with the tissues broken down and curdy.

Feeding Calf H with the milk of Cow 1337.—This was a strong, vigorous heifer calf, dropped by cow No. 1337, September 15, 1898. This calf suckled its dam from the time of birth until one year old, September 15, 1899. At this time it was a large, vigorous animal, and appeared fat and healthy. Calf H was kept in the same stable and yard with the cows until about nineteen months old (April, 1900). It was first tested with tuberculin December 22–23, 1898, and again June 2–3, 1899, but did not respond to either of these tests. At the test made December 1–2, 1899, calf H gave a marked response. This animal was kept in the same stable with the cows throughout the winter of 1899 and 1900. It was sent to Brighton to be killed under Government inspection, in April, 1900, but was considered too badly diseased for the flesh to be used as food, and was ordered destroyed.

Feeding Calf I with the milk of Cow 1344.—Calf I was dropped March 24, 1899, by a tuberculous cow owned by the College which was temporarily being kept at the Station barn. During the feeding period which followed this calf was kept in the same stable with the tuberculous cows. This calf was fed the milk of cow No. 1344 from the time of birth till about the middle of July, 1898. When a little over two months old, June 1–2, it responded to the tuberculin test, and again December 2–3, 1899. From about the middle of July until October,

1899, this calf was fed the milk of cow No. 1343. In October it was weaned, and was fed a hay and grain ration until it was killed, February 12, 1900. Post-mortem examination showed one posterior mediastinal gland affected with encysted tubercular material. As far as could be found there was no active tuberculosis present in the system.

Feeding Calf K with the milk of Cow 1343.—Calf K was dropped by cow No. 1343, December 23, 1899. From birth till May 26, 1900, this calf was kept in the second story of the barn, above the cows, in a room closed from the rest of the barn. It was thought that the animal was under conditions of thorough quarantine from the other animals in the barn. It was fed the normal milk of its dam for nearly three months before being tested. Calf K was tested with tuberculin March 19–20, 1900, and gave a marked response.

In order to test the question as to whether the transmission of the disease has probably taken place through the milk or by association with the cows, some new feeding tests are being planned for the summer and fall of 1900. In these tests the calves will be kept at pasture, entirely separate from all other animals, and the milk of the tuberculous cows will be carried to them.

SUMMARY OF FEEDING TESTS.

Within the first two years that the tuberculous cows were under experiment one secondary case of tuberculosis developed. This case was discovered about twenty-five months after the cows came to the Station. During this time four animals, A, B, C, and D, were fed the milk of the cows in periods ranging from eighteen months to twelve months. Throughout the whole of this time, except the five months while steers A and B were at pasture, the young animals were closely associated with the cows. As has already been shown, there was good reason for the belief that the disease was present in its earlier stages when the cows came to the Station. The first two years' experience then would seem to show that when the disease exists in the cow in its earlier stages the chances for its transmission, either by the milk or by other means, to calves associated with the cows are quite limited.

The balance of the time that the cows have been at the Station, which includes the period from about two years to three and

one-half years after their arrival, entirely different results are recorded. During the period from August 15, 1898, to March 20, 1900 (nineteen months), five animals were fed the milk of the same lot of cows, and all five responded to one or more tuberculin tests made within that period, and proved to be diseased. Two cases developed within three months after birth, while the other three required from twelve to eighteen months for their development. The physical condition of the cows, for the past year, would seem to indicate that the disease has progressed decidedly in at least three of the four cows.

PRACTICAL DEDUCTIONS.

During the first two years it was practically impossible to detect any outward signs of tuberculosis in the cows, and careful physical examination by an expert only revealed a possible presence of the disease in one of the four animals, and a probable diseased condition in one other. During the past year and one-half, however, there have been noticeable outward signs of poor health, pointing towards a tubercular condition, and physical examination showed quite conclusive evidence of the disease in three of the four animals. The fact that no secondary case of the disease developed until the calves had been fed the milk of the cows from one to one and one-half years, and had been associated with the cows for about two years, would seem to show that there is little danger of the spread of the disease, where it exists in the earlier stages.

In the feeding tests for the first two years the young animals to which the milk was fed were kept, most of the time, in the same stable with the cows. Four calves were fed the milk of the tuberculous cows in periods ranging from nine months to eighteen months without showing any signs of the disease. The first case among the young animals was discovered about six months after the feeding of milk was discontinued.

In the second lot of feeding tests six calves were fed. Three of these were kept in a separate part of the barn from the cows, and three in the same stable. Two calves, one in the stable and one kept in another part of the barn, responded to the tuberculin test within three months after the feeding of the milk was begun. Of the other four, two responded soon after returning from the pasture where they had been for four months following a feeding

period of ten months. Two others were in the same stable with the cows for periods of from three to six months, after feeding tests of ten and twelve months were ended, before showing any indications of the disease. These tests would seem to show that as the disease in the cows becomes advanced the milk becomes more infectious, and that there is great danger to the health of other animals, both from the use of the milk and by association with the diseased animals.

The results of these experiments coincide with the general results of European observations, and indicate that the danger from the spread of tuberculosis through the milk of cows to other animals is not as great as has often been supposed. In the earlier stages of the disease, and at all times when the udder is not affected, the danger from the use of the milk thus appears to be quite limited. Great stress, however, should be laid on the danger of using as food for man or animals milk from cows which show any symptoms of udder affection, or when the disease is so far advanced in the cows as to be indicated by outward signs or other marked physical symptoms.

FIELD EXPERIMENTS WITH FERTILIZERS.

BY W. O. ATWATER AND C. S. PHELPS.

Owing in part to the fact that a large amount of other important work was pressing for publication, the field experiments of 1897 and 1898 have not yet been reported upon. In this article, therefore, an account is given of the field work of the Station for the past three* years. The experiments for the most part are in continuation of those carried out in preceding years and described in former reports of the Station. The field experiments have been mainly along the following lines:

1. Special nitrogen experiments on corn, cow peas, and soy beans, for the purpose of studying the effects of nitrogen in different quantities and combinations in the fertilizers upon the yields and the composition of the crops.

2. A rotation soil test on the Station land, for the purpose of studying the deficiencies of the soil and the needs of different crops for the different ingredients of fertilizers.

3. Experiments with grasses and other forage crops, mainly for the purpose of comparing the feeding values of different fodder crops, and of studying the effects of the nitrogen in the fertilizers upon the proportion and amount of protein in the different crops.

4. An experiment on soil improvement, for the purpose of comparing the relative economy of (1) stable manure, (2) a "complete" chemical fertilizer, and (3) green manures alone and in connection with mineral fertilizers for improving a soil apparently deficient in organic matter and in available nitrogen.

The results of the special nitrogen experiments and of the soil tests, during the past three* years, are here given. The results of the experiments with grasses and forage crops will

* In the case of soy beans the experiments of 1896 are also included.

be given in a later Report with those of future experiments. The experiment on soil improvement was begun during the past year, and is to be continued for several years. An account of the nature and plan of this work and the results of the preliminary experiment are given in the article following this one.

SPECIAL NITROGEN EXPERIMENTS.

The special nitrogen experiments of the past three years are an extension of a series which was begun in 1895 and continued in 1896, as described in the Reports of the Station for those years. The crops with which the experiments are made are corn, cow peas, and soy beans. These are grown on plots treated with fertilizers supplying nitrogen, phosphoric acid, and potash in different amounts and combinations, in the manner described in a later paragraph, the special purpose of the experiments being to study the effects of the nitrogen in the fertilizer upon the yields and the composition of the crops.

The special nitrogen experiments with these crops are carried out on a series of plots which, prior to 1895, had been used for similar experiments with mixed grasses. For the earlier experiments with grasses the experimental field was divided into ten long, narrow plots, each one-eighth acre in size. These were numbered and fertilized as shown in the diagram on page 170.

From this diagram it will be seen that two plots, Nos. 0 and 00, receive no fertilizer, while each of the other plots receives dissolved bone-black at the rate of 320 pounds, with 53 pounds of phosphoric acid, per acre, and muriate of potash at the rate of 160 pounds, with 82 pounds of potash, per acre. For convenience this mixture of superphosphate and potash salt is called "mixed minerals." Plots 7, 8, and 9 received, in addition to the mixed minerals, respectively 160, 320, and 480 pounds of nitrate of soda, with 25, 50, and 75 pounds of nitrogen, per acre, and are called the nitrate of soda group; while plots 10, 11, and 12 received, in addition to the mixed minerals, respectively 160, 320, and 480 pounds of sulphate of ammonia, with 25, 50, and 75 pounds of nitrogen, per acre, and are called the sulphate of ammonia group. The adjoining plots are separated from each other by narrow strips that are not fertilized.

Diagram illustrating the method of dividing the experimental field into plots, and the kinds and amounts of fertilizers used on each plot.

Each plot is 272¼ feet long by 20 feet wide. The unmanured strips separating the adjoining plots are 3 feet wide. The weights of the fertilizers are per acre.

EAST.

NORTH. | SOUTH.

PLOT 0.	Nothing.	
PLOT 7.	Mixed minerals as Plot 6*a*, 480 lbs. Nitrate of Soda, - - 160 lbs.	Nitrogen, - 25 lbs.
PLOT 8.	Mixed minerals as Plot 6*a*, 480 lbs. Nitrate of Soda, - - 320 lbs.	Nitrogen, - 50 lbs.
PLOT 9.	Mixed minerals as Plot 6*a*, 480 lbs. Nitrate of Soda, - - 480 lbs.	Nitrogen, - 75 lbs.
PLOT 6*a*.	Dissolved Bone-black, - 320 lbs. Muriate of Potash, - 160 lbs.	"Mixed minerals."
PLOT 10.	Mixed minerals as Plot 6*a*, 480 lbs. Sulphate of Ammonia, 120 lbs.	Nitrogen, - 25 lbs.
PLOT 11.	Mixed minerals as Plot 6*a*, 480 lbs. Sulphate of Ammonia, 240 lbs.	Nitrogen, - 50 lbs.
PLOT 12.	Mixed minerals as Plot 6*a*, 480 lbs. Sulphate of Ammonia, 360 lbs.	Nitrogen, - 75 lbs.
PLOT 00.	Nothing.	
PLOT 6*b*.	Mixed minerals as Plot 6*a*, 480 lbs.	Phosphoric acid, 53 lbs. Potash, - - 82 lbs.

WEST.

In the experiments with grasses previous to 1895, each of these plots was fertilized in the manner just described year after year, and the same crop—mixed grasses—was grown on all of them. In the experiments with corn, cow peas, and soy beans, which have been carried out on the same plots since

1895, the same arrangement of the plots and the same method of fertilizing them has been continued, namely those shown in the preceding diagram. But for the purpose of the later experiments the plots, which extend north and south, are subdivided by paths crossing them from east to west, so that each plot contains six subdivisions or sections, each one-fiftieth of an acre in size. The method of dividing the plots into sections is illustrated by the diagram on page 172, which shows also the crop grown on each section.

It is hardly to be expected that the effects of the fertilizers upon the yields of the crops can be determined as accurately from experiments made on plots of this size as from experiments made on larger plots. This is a matter, however, that is already quite generally understood, so that the results of these experiments in this respect are neither novel nor striking. The more important object of the experiments, and one with which farmers are not so familiar, is the study of the effects of the nitrogen of the fertilizers upon the proportion of nitrogen in the crop. It is believed that in this respect the results are quite as reliable from the experiments made on the small plots as could be obtained if larger plots were used. The particular advantage in the small plots is that a larger number of crops can be used for the experiments. Three different crops were grown on each plot, and the number might have been six.

The numbers of the plots in the diagram on page 172 are given at both ends of each plot. For convenience in referring to the sections they are designated by letters, A, B, C, etc., beginning with the section at the north end of each plot, and lettering to the south, as indicated for plots 0 and *6b* in the diagram. A series of sections will include all the sections of the same letter. Thus, in discussing the experiments with corn, for instance, "Series A" will include all the sections at the north ends of the ten plots, and "Series F" will include all the sections at the south ends of the plots. It will be observed that each crop is grown on two sections of each plot; that is, upon two series of sections. In the accounts of some of the experiments the results from two series with the same crop are combined as if from a single series of sections twice the size of these; while in other experiments the results from each series are considered separately.

Diagram illustrating the method of dividing the plots into sections, and the kind of crop planted on each section.

The plots are fertilized exactly as shown in the preceding diagram. The plots are indicated by numbers, the sections by letters.

EAST.

NORTH.

	A	B	C	D	E	F	
0	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	0
7	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	7
8	Corn.	Soy beans	Cow peas.	Cow peas.	Soy beans.	Corn.	8
9	Corn.	Soy beans.	Cow peas	Cow peas.	Soy beans.	Corn.	9
6*a*	Corn.	Soy beans	Cow peas.	Cow peas.	Soy beans.	Corn.	6*a*
10	Corn.	Soy beans.	Cow peas.	Cow peas	Soy beans.	Corn.	10
11	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	11
12	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	12
00	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	00
6*b*	Corn.	Soy beans.	Cow peas.	Cow peas.	Soy beans.	Corn.	6*b*
	A	B	C	D	E	F	

SOUTH.

WEST.

Explanation of tables.—Two tables, containing the data of the experiments, are given in the discussion of the results for each crop. The first table in each case shows the total weight of the crop taken from each section, the crops being weighed either at the time of harvesting or after drying in the field. In the experiments with corn and soy beans the total grain or seed from each plot was taken to the barn and allowed to dry before it was weighed. The corn stover was weighed after it had dried in the field. The cow pea fodder was weighed green as soon as possible after it was cut. The table shows also the estimated yields per acre for each crop as calculated from the size of the section and the weight of the crop taken from it, as well as the increase in the weight of the crop from the plots with the different fertilizers over the weight of the crop from the plots with no fertilizer. The costs of the fertilizers given in one column of the table are based upon the system of valuation adopted each year by the New England Experiment Stations, which varies slightly from year to year. For the years in which experiments reported in this article were made the valuations per pound of the different ingredients of fertilizers were as follows:

Assumed costs per pound.

	1896.	1897.	1898.	1899.
	Cents.	Cents.	Cents.	Cents.
Nitrogen (as nitrate of soda), - -	13½	14	14	12½
Nitrogen (as sulphate of ammonia), -	15	13½	14	15
Phosphoric acid (soluble*), - - -	5½	5½	4½	4½
Potash (as muriate), - - - - -	4½	4½	4½	4½

The second table in each case shows the estimated total yields of the crop per acre, the percentage of water-free substance or dry matter in the crop when weighed, the percentage of protein (N. $\times$ 6.25) in the dry matter, and the calculated yields of dry matter and of protein. The total yield of dry matter per acre is found by multiplying the total weight of the crop by the percentage of dry matter in it; and the total yield of protein per acre is found by multiplying the yield of dry matter per

* A small proportion of the phosphoric acid was probably present in the form known as "reverted," but the valuation for this is only one-half cent less per pound than for the soluble.

acre by its percentage of protein. The last two columns of the table show the percentage of the yields of dry matter and of protein from each plot if the average of the yields from the mineral plots be taken as a basis.

In making the analyses of the samples of these field crops tests for nitric acid were made in a considerable number of samples, especially those from the plots in which the largest quantities of nitrogen in nitric acid and other forms were applied in the fertilizers. The tests were made by treating cold water extracts with a sulphuric acid solution of di-phenylamin. The deep color of the extract interfered somewhat with the reactions and prevented quantitative determinations. But it was estimated that in no instance was the amount of nitric acid indicated sufficient to make one per cent. of the total nitrogen found in the samples.

In 1897 the experiments were vitiated by excessive rains during the growing season. The nitrogenous fertilizers failed to produce results in amount and uniformity of yield such as had been obtained in other years. This may have been due to a loss of the materials in which the nitrogen was supplied to the soil, these being readily washed out of the soil by heavy rains when they are not taken up by the plants. The weights of the crops when harvested in 1897 were considerably below those of former years, and the general irregularities of the experiments indicated that the results as a whole would not warrant the usual analyses. In the tables giving the data of the experiments, therefore, only the weights of the crops at harvest are found for 1897*, and these are so unusually low that they are not included in the averages. The results of the experiments of 1898 and 1899 appear to be fairly normal.

EXPERIMENTS WITH CORN.

When these experiments were begun in 1895 two varieties of corn, "yellow flint" and "white flint," were grown. Analyses of samples of the grain used for seed in the first of the experiments, in 1895, showed a difference in the composition of the two varieties, the white flint corn having thirteen per cent. of protein in the dry matter of the grain, while the yellow flint contained only eleven per cent. The latter had been grown upon poor soil for many years.

* Except cow pea fodder, of which analyses also were made.

One object of the experiments was to determine whether the two varieties, which differed so much in composition at the beginning of the experiments, would still show the same difference after they had been grown for a period of years under the same conditions regarding methods of cultivation, kinds and amounts of fertilizer used, etc. For three years the experiments with these two varieties of corn were carried on, seed taken from the crop on each section in one year being saved for planting on the same section the following year. To prevent, if possible, a crossing of the varieties that might follow if they were grown on adjoining sections, the yellow flint corn was grown on the series of sections at the north end of the plots (Series A), and the white flint on the series of sections at the south end (Series F), the two series being about 175 feet apart. In spite of this separation a slight amount of mixing or crossing occurred during the first year (1895). Care was taken, however, in saving the seed for the following year, to select that which was believed to be unmixed. In 1896 the yellow flint corn, which was naturally somewhat slower than the white flint in reaching maturity, was planted a week later than the white flint, so that the blossoming of the two varieties might occur at different periods. In that year mixing or crossing of the varieties was apparently prevented. The seed from the experiments of 1896 was planted as usual in 1897, but in the wet, cool season of that year the yellow flint corn failed to mature sufficiently to warrant the use of the seed for planting in 1898; and as it was found impossible to secure more seed of the same variety from the grower who furnished in 1895 the seed used in the first of these experiments, the use of the yellow flint corn was discontinued in 1898, and since that time, as will be explained in a later paragraph, only white flint corn has been used.

The results of the experiments for 1895 and 1896 may be found in the Reports of the Station for those years. The results of the 1897 experiments are incorporated with those of 1898 and 1899 in the present article. As already explained, the crops grown in the experiments of 1897 were not analyzed, only the weights of the crops at harvest being given in the following tables; and these are so irregular that they are not

included in the general averages. No attempt is made, therefore, to draw conclusions concerning the effects of the fertilizers from the experiments of that year.

The experiments of 1895 and 1896 indicate, in brief, that as regards both yield and composition the nitrogenous fertilizers benefited greatly both the corn and the stover in the two varieties. The yields from the plots with nitrogenous fertilizers were considerably larger than those from the plots which had the mineral fertilizers only or no fertilizers at all. The proportion of protein in the crops was higher where nitrogen was used in the fertilizer, although the percentage of protein did not increase in proportion to the amount of nitrogen used. The percentage of protein in the seed taken from the 1896 crops for planting in 1897 was not so large in either variety as was found in the original seed planted in 1895; the average composition of the grain of each variety from all the plots showing only 11 per cent. of protein in the white flint in the latter season, as against 13 per cent. in the original sample; and the yellow flint 10.2 per cent. in the latter season as against 11 per cent. in the original sample. The experiment with the two varieties was not continued long enough, however, to draw any conclusions from these results regarding the relative tendencies to maintain, increase or diminish their percentages of nitrogen under the different methods of fertilizing.

Inasmuch as for lack of proper seed the experiment with yellow flint corn could not be continued, a new lot of white flint corn was obtained in 1898 from the grower who had furnished the seed of this variety in 1895, and this new lot of seed was planted on the sections (Series A) previously devoted to yellow flint corn, and since that time only the one variety—white flint—has been used in these experiments with corn. The sections (Series F) at the south end of the field, however, were planted with seed grown on the same sections in the preceding year. There was, therefore, a difference in the conditions under which the two lots of seed had been grown prior to 1898. Furthermore, a difference was made in the fertilizing of the two series (A and F), as explained in the next paragraph; lime being applied on Series A in addition to the regular fertilizers, while on Series F no lime was applied in addition. For these reasons it was thought best to keep the data from the two series separate, as is done in Tables 37 and 38.

In earlier experiments on this field it had been observed that yields from some of the plots of the sulphate of ammonia group were smaller than those from corresponding plots of the nitrate of soda group, the differences being most conspicuous in the cases where the largest amounts of the sulphate were used. Experiments* elsewhere, however, have given similar results, and suggest that the smaller yield with the sulphate of ammonia may be due to an acid condition of the soil resulting from the surplus sulphuric acid left as a residue in the soil after the nitrification of the ammonia of the sulphate. In these latter experiments air-slacked lime was applied for the purpose of neutralizing the acidity, apparently with excellent results. Accordingly, in the experiments at the Station in 1898, forty pounds of air-slacked lime was applied, in addition to the regular fertilizer, on each section in Series A at the north end of the field upon which the new lot of seed was planted in 1898. On the sections at the south end of the plots (Series F), which were planted with corn grown on the same sections, the fertilizers were applied without the additional lime. A comparison of the yields from the two series, the one with and the other without the extra lime, is given in the following table. The figures in this table are the averages of the results of the experiments of 1898 and 1899 given in Tables 37 and 38 following.

Yields of corn and stover from sections treated with lime compared with yields from sections not treated with lime.

Kind of Fertilizer.	Plot No.	Yields per Acre.			
		Series F, without lime.		Series A, with lime.	
		Shelled corn.	Stover.	Shelled corn.	Stover.
		bu.	lbs.	bu.	lbs.
Nothing,	0, 00	15.3	901	12.7	1139
Mixed minerals	6*a*, 6*b*	31.7	2216	36.6	2647
Nitrate of soda group,	7	28.8	2013	35.2	2575
	8	42.5	2480	52.6	3000
	9	43.6	2310	52.0	2675
Sulphate of ammonia group,	10	39.9	2463	48.6	2938
	11	44.0	2438	48.2	3600
	12	36.0	1995	51.4	3200

* For a discussion of the subject of the acidity of soils and the beneficial action of lime upon acid soils, see articles by H. J. Wheeler, Ph. D., in the Reports and Bulletins of the R. I. Experiment Station. See also U. S. Dept. Agr., Farmers' Bulletin, No. 77, The Liming of Soils, by the same author.

It will be observed that on the sections without additional lime the yield from plot 12, having the largest ration of sulphate of ammonia, was considerably smaller than that from plot 9, having the largest ration of nitrate of soda; while on the sections treated with lime in addition to the regular fertilizers the yield from plot 12 was practically the same as that from plot 9. If the difference between the yield with the sulphate and that with the nitrate is due to an acid condition of soil caused by the former material, then in this particular case it would seem not improbable that the sulphuric acid from the ammonium sulphate might have been neutralized by the lime. It is not meant by this, however, that the neutralizing of sulphuric acid set free by the nitrification of ammonia, or of acids otherwise formed in the soil, is the sole or necessarily the chief factor to be considered in explaining the beneficial action of lime. Indeed, the results of experiments for 1898 and 1899, as seen in the table above, show that the yields from all the fertilized sections, which were treated with lime in addition to the regular fertilizers (not considering the plots with no fertilizer), were better than the yields from sections without lime. The fact that where lime was used there was a considerable increase in the yields from the nitrate of soda group as well as in those from the sulphate of ammonia group of plots would seem to indicate that the lime had some direct beneficial effect upon the fertility of the soils aside from its neutralizing action, as nitrate of soda would hardly cause injurious acidity. It may be that the lime aided in the nitrification of the ammonia of the sulphate and of other nitrogen compounds present in the soil. In how far this may be the case these experiments are not calculated to indicate.

The amounts of nitrogen in the fertilizers and the yields of the crop.—The figures in the following tables are intended to show what increase in the total yield (corn and stover) accompanies the increase in the amount of nitrogen in the fertilizer. The yields from the sections (Series A) at the north ends of the plots are given in Table 37; those from sections at the south ends (Series F) in Table 38. The weights of the yields are given per section and per acre. The yields per section are determined by actual weighings of the crop from each section.

From these weighings and the size of the plots the corresponding yields per acre are calculated. By comparing the yields from the sections having different kinds and amounts of fertilizers the effect of the different fertilizers upon the yields may be estimated.

As might be expected, the yields from the sections of plots 0 and 00, which have received no fertilizer for over ten years, are poor. The yields from the section of plots 6*a* and 6*b*, which have only the mineral fertilizers, are much better than might be expected in consideration of the fact that no nitrogenous fertilizers of any kind have been applied upon these plots for more than ten years. In this respect the results of the experiments with corn are much better than those obtained in experiments with common grasses, such as timothy or red top, under similar conditions. This accords with the belief that corn may be better able than the common grasses to gather nitrogen from natural sources in the soil.

In the average of the results from both series of sections A and F for 1898 and 1899 the yields from the sections of plot 7, with the smaller ration of nitrate of soda, are smaller than those from the sections of the mineral plots, 6*a* and 6*b*. This smaller yield with nitrogenous fertilizers than without them is unusual, and the explanation is not apparent.

In comparing the yields of shelled corn from the sections of the different plots it will be noticed that, with one exception, the yields from the sections of the nitrate of soda group of plots, 7, 8, and 9, are largest from plot 9, upon which the largest ration—seventy-five pounds per acre—of nitrogen is used. It will be observed, however, that the yields from plot 9 are but little larger than those from plot 8, upon which only fifty pounds of nitrogen per acre are used; while in the exception noted above in 1899 the yield from section A of plot 8 was larger than that from the same section of any other plot. This generally small increase in yield of crop accompanying a relatively large increase in the quantity of nitrogen in the fertilizers would seem to indicate that the corn in this case could not utilize profitably the larger quantities of nitrogen when supplied in a readily soluble fertilizer such as nitrate of soda.

TABLE 37.

SPECIAL NITROGEN EXPERIMENTS ON WHITE* FLINT CORN (SERIES A).

Weight and cost of fertilizers per acre, total crop, and increase of crop over that of the nothing plots.

No. of Plot.	Fertilizers per Acre. Kind.	Weight.	Year.	Cost.	Yield per Sec. 1-50 Acre. Shelled corn.	Yield per Sec. 1-50 Acre. Stover.	Yield per Acre. Shelled corn.	Yield per Acre. Stover.	Gain over nothing plots.
		Lbs.		$	Lbs.	Lbs.	Bu.	Lbs.	Bu.
0	Nothing, - - - - -	—	1897		2.7	23.5	2.4	1175	—
			1898		11.3	25.0	10.1	1250	—
			1899	—	12.2	19.6	10.9	980	—
			Av.†		**11.8**	**22.3**	**10.5**	**1115**	
7	Mixed Minerals, as No. 6*a*, -	480	1897	10.11	4.0	45.0	3.6	2250	-0.4
	Nitrate of Soda, (25 lbs. N.),	160	1898	9.37	33.3	45.0	29.7	2250	15.5
			1899	9.00	45.5	58.0	40.7	2900	29.4
			Av.†		**39.4**	**51.5**	**35.2**	**2575**	**22.5**
8	Mixed Minerals, as No. 6*a*, -	480	1897	13.61	12.5	29.5	11.2	1475	7.2
	Nitrate of Soda, (50 lbs. N.),	320	1898	12.87	52.5	50.5	46.9	2525	32.7
			1899	12.13	65.2	69.5	58.2	3475	46.9
			Av.†		**58.9**	**60.0**	**52.6**	**3000**	**39.8**
9	Mixed Minerals, as No. 6*a*, -	480	1897	17.11	10.6	31.5	9.5	1575	5.5
	Nitrate of Soda, (75 lbs. N.),	480	1898	16.37	56.5	59.5	50.5	2975	36.3
			1899	15.26	59.8	47.5	53.4	2375	42.1
			Av.†		**58.2**	**53.5**	**52.0**	**2675**	**39.2**
6*a*	Dis. Bone-black, Mixed Minerals,	320	1897	6.61	11.1	25.0	9.9	1250	5.9
	Mur. of Potash, Mixed Minerals,	160	1898	5.87	32.5	43.0	29.0	2150	14.8
			1899	5.87	40.9	70.3	36.5	3515	25.2
			Av.†		**36.7**	**56.7**	**32.8**	**2833**	**20.0**
10	Mixed Minerals, as No. 6*a*, -	480	1897	9.99	21.3	34.5	19.0	1725	15.0
	Sulph. of Am. (25 lbs. N.), -	120	1898	9.37	45.5	53.0	40.6	2650	26.4
			1899	9.62	63.3	64.5	56.6	3225	45.3
			Av.†		**54.4**	**58.8**	**48.6**	**2938**	**35.9**
11	Mixed Minerals, as No. 6*a*, -	480	1897	13.37	27.0	37.0	24.1	1850	20.1
	Sulph. of Am. (50 lbs. N.), -	240	1898	12.87	58.7	64.0	52.4	3200	38.2
			1899	13.37	49.3	80.0	44.0	4000	32.7
			Av.†		**54.0**	**72.0**	**48.2**	**3600**	**35.5**
12	Mixed Minerals, as No. 6*a*, -	480	1897	16.75	27.0	41.0	24.1	2050	20.1
	Sulph. of Am. (75 lbs. N.), -	360	1898	16.37	55.8	50.5	49.8	2525	35.6
			1899	17.12	59.2	77.5	52.9	3875	41.6
			Av.†		**57.5**	**64.0**	**51.4**	**3200**	**38.6**
00	Nothing, - - - - -	—	1897		6.3	22.0	5.6	1100	—
			1898		20.5	25.0	18.3	1250	—
			1899	—	13.0	21.5	11.6	1075	—
			Av.†		**16.8**	**23.3**	**15.0**	**1163**	
6*b*	Mixed Minerals, as No. 6*a*, -	480	1897	6.61	6.7	39.0	6.0	1950	2.0
			1898	5.87	45.0	41.0	40.2	2050	26.0
			1899	5.87	45.7	57.5	40.8	2875	29.5
			Av.†		**45.4**	**49.3**	**40.5**	**2463**	**27.8**

* Yellow flint corn in 1897.

† Average omitting 1897.

TABLE 38.

SPECIAL NITROGEN EXPERIMENTS ON WHITE FLINT CORN (SERIES F).

Weight and cost of fertilizers per acre, total crop, and increase of crop over that of the nothing plots.

No. of Plot.	Fertilizers per Acre. Kind.	Weight.	Year.	Cost.	Yield per Sec. 1-50 Acre. Shelled corn.	Yield per Sec. 1-50 Acre. Stover.	Yield per Acre. Shelled corn.	Yield per Acre. Stover.	Gain over nothing plots.
		Lbs.		$	Lbs.	Lbs.	Bu.	Lbs.	Bu.
0	Nothing, - - - - -	—	1897	—	7.7	12.5	6.9	625	—
			1898		14.2	16.1	12.7	805	—
			1899		20.2	23.8	18.0	1190	—
			Av.*		**17.2**	**20.0**	**15.4**	**998**	—
7	Mixed Minerals, as No. 6*a*,	480	1897	10.11	24.7	26.0	22.1	1300	13.8
	Nitrate of Soda, (25 lbs. N.),	160	1898	9.37	28.0	27.0	25.0	1350	10.1
			1899	9.00	36.4	53.5	32.5	2675	16.7
			Av.*		**32.2**	**40.3**	**28.8**	**2013**	**13.4**
8	Mixed Minerals, as No. 6*a*,	480	1897	13.61	15.4	27.0	13.8	1350	5.5
	Nitrate of Soda, (50 lbs. N.),	320	1898	12.87	47.7	44.2	42.6	2210	27.7
			1899	12.13	47.4	55.0	42.3	2750	26.7
			Av.*		**47.6**	**49.6**	**42.5**	**2480**	**27.2**
9	Mixed Minerals, as No. 6*a*,	480	1897	17.11	31.5	25.0	28.1	1250	19.8
	Nitrate of Soda, (75 lbs. N.),	480	1898	16.37	48.1	41.4	42.9	2070	28.0
			1899	15.26	49.4	51.0	44.2	2550	28.4
			Av.*		**48.8**	**46.2**	**43.6**	**2310**	**28.2**
6*a*	Dis. Bone-black, } Mixed Minerals,	320	1897	6.61	25.9	22.0	23.1	1100	14.8
	Mur. of Potash, } Mixed Minerals,	160	1898	5.87	36.9	35.8	32.9	1790	18.0
			1899	5.87	33.0	52.0	29.5	2600	13.7
			Av.*		**35.0**	**43.9**	**31.2**	**2195**	**15.9**
10	Mixed Minerals, as No. 6*a*,	480	1897	9.99	29.9	33.0	26.7	1650	18.4
	Sulph. of Am. (25 lbs. N.), -	120	1898	9.37	43.0	40.5	38.4	2025	23.5
			1899	9.62	46.3	58.0	41.3	2900	25.6
			Av.*		**44.7**	**49.3**	**39.9**	**2463**	**24.6**
11	Mixed Minerals, as No. 6*a*,	480	1897	13.37	39.6	33.0	35.4	1650	27.1
	Sulph. of Am. (50 lbs. N.), -	240	1898	12.87	47.7	44.5	42.6	2225	27.7
			1899	13.37	50.8	53.0	45.4	2650	29.6
			Av.*		**49.3**	**48.8**	**44.0**	**2438**	**28.7**
12	Mixed Minerals, as No. 6*a*,	480	1897	16.75	38.5	32.0	34.4	1600	26.1
	Sulph. of Am. (75 lbs. N.), -	360	1898	16.37	43.2	37.8	38.6	1890	23.7
			1899	17.12	36.4	42.0	33.4	2100	17.6
			Av.*		**39.8**	**39.9**	**36.0**	**1995**	**20.7**
00	Nothing, - - - - -	—	1897	—	10.7	10.0	9.6	500	—
			1898		19.0	14.7	17.0	735	—
			1899		15.1	17.5	13.5	875	—
			Av.*		**17.1**	**16.1**	**15.3**	**805**	—
6*b*	Mixed Minerals, as No. 6*a*,	480	1897	6.61	25.3	29.0	22.6	1450	14.3
			1898	5.87	41.8	37.0	37.3	1850	22.4
			1899	5.87	30.3	52.5	27.1	2625	11.3
			Av.*		**36.1**	**44.8**	**32.2**	**2238**	**16.9**

* Average omitting 1897.

From a comparison of the yields of shelled corn from all the sections in the same series it will be seen that the yields from the sections of the sulphate of ammonia group of plots—10, 11, and 12—correspond somewhat with those from the nitrate of soda group—7, 8, and 9—the most noticeable disagreement being that between the yields from section F of plot 12, with the large ration of sulphate of ammonia, and the yield from section F of plot 9, with the large ration of nitrate of soda. That the smaller yield from plot 12 may be due to acidity of the soil has already been suggested.

The amounts of nitrogen in the fertilizers and the proportion of protein in the crop.—The following tables are intended to illustrate, by the analyses of the crops, the apparent effects of the different fertilizers upon the composition of the plants, and especially the increase in the proportion of nitrogen in the crops following the increase in the quantity of nitrogen in the fertilizers. The results for the grain and the stover respectively are shown in Tables 39 and 40 for the sections (Series A) at the north end of the plots, and in Tables 41 and 42 for the sections (Series F) at the south end. The data in these tables include the weights per acre of the crops on the different sections at harvest, the percentages and amounts of dry matter and of protein in the crop, and a comparison—expressed in percentages in the last two columns—of the yields of dry matter and of protein from the sections of plots having nitrogen with the average of the yields from sections of the mineral plots. This comparison between the results from sections of the mineral plots and those from sections of plots with nitrogenous fertilizers in addition to the minerals shows the increase in dry matter and protein that follows the use of the nitrogenous fertilizers, and serves to indicate the relative effects of the different quantities of nitrogen upon the proportion of nitrogenous compounds (protein) in the crops.

We here follow common usage in multiplying the total nitrogen found by analysis by the factor 6.25 and designate the product as protein. It is, of course, understood that not all of the nitrogen is present in the plant in the form of true proteids. More or less occurs in non-proteid organic compounds. Small quantities are at times present in plants in the form of nitrates.

The methods for distinguishing between proteid and non-proteid nitrogen are not satisfactory. We nevertheless hope at some future time to inquire into the quantities of proteid and non-proteid nitrogen in the plants grown on the different plots in these experiments, even though there is little reason to believe that the results will prove of special importance. Had the resources of the Station allowed it this would have been done already.

In view of the possibility of the occurrence of nitrogen in the form of nitrates a number of tests were made for nitric acid in samples of crops from plots on which the nitrogenous fertilizers were applied, but the results of the tests were negative, as stated on page 174.

From the figures in these tables it will be noticed that in many instances the percentage of protein is higher in crops grown with no fertilizers than it is in crops grown with fertilizers. This same thing has been observed in previous experiments, and is explained in former Reports* as probably due to the fact that in the grain grown without fertilizers there is a large proportion of "poor" or "soft" kernels. These latter have been shown by analysis to contain a larger percentage of protein than is found in matured corn, owing possibly to an incomplete development of starch and oil in the immature seeds. In the crop from sections of the mineral plots (6*a* and 6*b*) the percentages of protein are seen to be in nearly all cases smaller than in the crops from sections of plots with nitrogen. In plants from the nitrate of soda group of plots the percentages of protein were largest in both grain and stover from sections of plot 9. The increase, however, in the protein in the crops from sections of plot 9 over that in the crops from sections of plot 8 did not correspond in all cases to the increase in the quantity of nitrogen in the fertilizers. In many instances the percentage of protein in crops from sections of plot 9, with seventy-five pounds of nitrogen per acre, are but little larger than in those from sections of plots 8 or 7, with fifty or twenty-five pounds of nitrogen per acre. Similar facts are noticed in the results from the sulphate of ammonia group of plots.

* See p. 28 of the Report of this Station for 1890; also p. 136 of Report for 1898.

TABLE 39.

SPECIAL NITROGEN EXPERIMENTS ON WHITE FLINT CORN (SERIES A).

Percentages and pounds per acre of dry matter and of protein in the grain.

No. of Plot.	FERTILIZERS.	Weight of fertilizer.	Year.	Weight at harvest per acre.	Dry matter.		Protein in dry matter. N. × 6.25.		Percentage of yield on basis of yield from mineral plots.	
									Dry matter.	Protein.
		Lbs.		Lbs.	%	Lbs.	%	Lbs	%	%
0	Nothing, - - - - -	—	1898	565	84.3	476	9.79	47	29	29
			1899	610	89.7	547	10.19	56	29	29
			Av.	**588**	**87.0**	**512**	**9.99**	**52**	**29**	**30**
7	Mixed Minerals, as No. 6*a*,	480	1898	1665	81.5	1357	10.35	140	82	87
	Nitrate of Soda (25 lbs. N.),	160	1899	2275	88.9	2022	10.31	209	106	109
			Av.	**1970**	**85.2**	**1690**	**10.33**	**175**	**95**	**99**
8	Mixed Minerals, as No. 6*a*,	480	1898	2625	84.6	2221	10.05	223	134	139
	Nitrate of Soda (50 lbs. N.),	320	1899	3260	86.5	2820	10.94	309	148	161
			Av.	**2943**	**85.6**	**2521**	**10.50**	**266**	**142**	**151**
9	Mixed Minerals, as No. 6*a*.	480	1898	2825	83.1	2348	10.60	249	142	155
	Nitrate of Soda (75 lbs. N.),	480	1899	2990	87.3	2610	11.37	297	137	155
			Av.	**2908**	**85.2**	**2479**	**10.99**	**273**	**139**	**155**
6*a*	Dis. Bone-black, } Mixed	320	1898	1625	85.0	1381	9.70	134	*	*
	Mur. of Potash, } Min'ls,	160	1899	2045	87.4	1787	10.31	184	*	*
			Av.	**1835**	**86.2**	**1584**	**10.01**	**159**	*	*
10	Mixed Minerals, as No. 6*a*,	480	1898	2275	83.4	1897	10.12	192	115	120
	Sulph. of Am. (25 lbs. N.),	120	1899	3165	85.4	2703	11.56	313	142	163
			Av.	**2720**	**84.4**	**2300**	**10.84**	**253**	**129**	**143**
11	Mixed Minerals, as No. 6*a*,	480	1898	2935	85.8	2518	9.98	251	152	156
	Sulph. of Am. (50 lbs. N.),	240	1899	2465	85.5	2108	11.63	245	111	128
			Av.	**2700**	**85.7**	**2313**	**10.81**	**248**	**130**	**141**
12	Mixed Minerals, as No. 6*a*,	480	1898	2790	85.1	2374	10.43	248	144	155
	Sulph. of Am. (75 lbs. N.),	360	1899	2960	86.2	2552	11.50	294	134	153
			Av.	**2875**	**85.7**	**2463**	**10.97**	**271**	**138**	**154**
00	Nothing, - - - - -	—	1898	1025	83.2	853	10.59	90	52	56
			1899	650	89.6	582	11.19	65	31	34
			Av.	**836**	**86.4**	**718**	**10.89**	**78**	**40**	**44**
6*b*	Mixed Minerals, as No. 6*a*,	480	1898	2250	85.6	1926	9.71	187	*	*
			1899	2285	88.5	2022	9.87	200	*	*
			Av.	**2268**	**87.1**	**1974**	**9.79**	**194**	*	*

* The average of the yields on plots 6*a* and 6*b* is here taken at 100 for comparison.

TABLE 40.

SPECIAL NITROGEN EXPERIMENTS ON WHITE FLINT CORN (SERIES A).

Percentages and pounds per acre of dry matter and of protein in stover.

No. of Plot.	FERTILIZERS.	Weight of fertilizer.	Year.	Weight at harvest per acre.	Dry matter.		Protein in dry matter. N. × 6.25.		Percentage of yield on basis of yield from mineral plots. Dry matter.	Percentage of yield on basis of yield from mineral plots. Protein.
		Lbs.		Lbs.	%	Lbs.	%	Lbs	%	%
			1898	1250	68.6	858	7.84	67	62	73
0	Nothing, - - - - -	—	1899	980	68.3	669	9.00	60	36	52
			Av.	**1115**	**68.5**	**764**	**8.42**	**64**	**47**	**61**
	Mixed Minerals, as No. 6*a*,	480	1898	2250	64.3	1447	6.23	90	105	90
7	Nitrate of Soda (25 lbs. N.).	160	1899	2900	57.2	1659	6.19	103	89	88
			Av.	**2575**	**60.8**	**1553**	**6.21**	**97**	**96**	**93**
	Mixed Minerals, as No. 6*a*,	480	1898	2525	70.3	1775	5.71	101	129	110
8	Nitrate of Soda (50 lbs. N.),	320	1899	3475	62.7	2179	7.50	163	117	140
			Av.	**3000**	**66.5**	**1977**	**6.61**	**132**	**122**	**126**
	Mixed Minerals, as No. 6*a*,	480	1898	2975	58.0	1726	6.25	108	126	118
9	Nitrate of Soda (75 lbs. N.),	480	1899	2375	56.5	1342	7.19	97	72	83
			Av.	**2675**	**57.3**	**1534**	**6.72**	**103**	**95**	**99**
	Dis. Bone-black, } Mixed Min'ls,	320	1898	2150	62.8	1350	6.81	92	*	*
6*a*	Mur. of Potash,	160	1899	3515	57.9	2035	6.62	135	*	*
			Av.	**2833**	**60.4**	**1693**	**6.72**	**114**	*	*
	Mixed Minerals, as No. 6*a*,	480	1898	2650	66.4	1760	5.83	103	128	113
10	Sulph. of Am. (25 lbs. N.),	120	1899	3225	60.7	1958	7.81	153	105	131
			Av.	**2938**	**63.6**	**1859**	**6.82**	**128**	**115**	**122**
	Mixed Minerals, as No. 6*a*,	480	1898	3200	57.6	1843	6.09	112	134	122
11	Sulph. of Am. (50 lbs. N.),	240	1899	4000	55.0	2200	7.94	175	118	150
			Av.	**3600**	**56.3**	**2022**	**7.02**	**144**	**125**	**138**
	Mixed Minerals, as No. 6*a*,	480	1898	2525	61.6	1555	6.82	106	113	116
12	Sulph. of Am. (75 lbs. N.),	360	1899	3875	50.4	1953	8.19	160	105	137
			Av.	**3200**	**56.0**	**1754**	**7.51**	**133**	**108**	**127**
			1898	1250	62.0	775	9.08	70	56	77
00	Nothing, - - - - -	—	1899	1075	68.1	732	11.63	85	39	73
			Av.	**1163**	**65.1**	**754**	**10.36**	**78**	**47**	**75**
			1898	2050	68.2	1398	6.47	91	*	*
6*b*	Mixed Minerals, as No. 6*a*,	480	1899	2875	58.7	1688	5.81	98	*	*
			Av.	**2463**	**63.5**	**1543**	**6.14**	**95**	*	*

* The average of the yields on plots 6*a* and 6*b* is here taken at 100 for comparison.

TABLE 41.

SPECIAL NITROGEN EXPERIMENTS ON WHITE FLINT CORN (SERIES F).

Percentages and pounds per acre of dry matter and of protein in the grain.

No. of Plot.	FERTILIZERS.	Weight of fertilizer.	Year.	Weight at harvest per acre.	Dry matter.		Protein in dry matter. N. × 6.25.		Percentage of yield on basis of yield from mineral plots. Dry matter.	Percentage of yield on basis of yield from mineral plots. Protein.
		Lbs.		Lbs.	%	Lbs.	%	Lbs	%	%
0	Nothing, - - - - -	—	1898	710	88.2	626	10.70	67	37	41
			1899	1010	88.3	892	11.19	100	65	78
			Av.	**860**	**88.3**	**759**	**10.95**	**84**	**49**	**57**
7	Mixed Minerals, as No. 6a,	480	1898	1400	85.6	1198	10.51	126	71	76
	Nitrate of Soda (25 lbs. N.),	160	1899	1820	88.8	1616	10.00	162	117	126
			Av.	**1610**	**87.2**	**1407**	**10.26**	**144**	**92**	**98**
8	Mixed Minerals, as No. 6a,	480	1898	2385	86.1	2053	10.39	213	121	129
	Nitrate of Soda (50 lbs. N.),	320	1899	2370	88.7	2102	10.00	210	152	163
			Av.	**2378**	**87.4**	**2078**	**10.20**	**212**	**135**	**144**
9	Mixed Minerals, as No. 6a,	480	1898	2405	84.9	2042	11.41	233	121	141
	Nitrate of Soda (75 lbs. N.),	480	1899	2470	86.4	2134	11.12	237	155	184
			Av.	**2438**	**85.7**	**2088**	**11.27**	**235**	**136**	**159**
6a	Dis. Bone-black, } Mixed	320	1898	1845	86.6	1598	9.75	156	*	*
	Mur. of Potash, } Min'ls,	160	1899	1650	87.1	1437	9.13	131	*	*
			Av.	**1748**	**86.9**	**1518**	**9.44**	**144**	*	*
10	Mixed Minerals, as No. 6a,	480	1898	2150	84.4	1815	10.60	192	107	116
	Sulph. of Am. (25 lbs. N.),	120	1899	2315	88.7	2053	10.06	207	149	161
			Av.	**2233**	**86.6**	**1934**	**10.33**	**200**	**126**	**136**
11	Mixed Minerals, as No. 6a,	480	1898	2385	83.6	1994	10.54	210	118	127
	Sulph. of Am. (50 lbs. N.),	240	1899	2540	88.1	2238	10.63	238	162	185
			Av.	**2463**	**85.9**	**2116**	**10.59**	**224**	**138**	**152**
12	Mixed Minerals, as No. 6a,	480	1898	2160	84.5	1825	10.80	197	108	119
	Sulph. of Am. (75 lbs. N.),	360	1899	1820	86.2	1569	10.81	170	114	132
			Av.	**1990**	**85.4**	**1697**	**10.81**	**184**	**111**	**125**
00	Nothing, - - - - -	—	1898	950	84.9	807	10.90	88	48	53
			1899	755	87.3	659	11.19	74	48	58
			Av.	**853**	**86.1**	**733**	**11.05**	**81**	**48**	**55**
6b	Mixed Minerals, as No. 6a,	480	1898	2090	85.3	1783	9.82	175	*	*
			1899	1515	87.2	1321	9.56	126	*	*
			Av.	**1803**	**86.3**	**1552**	**9.69**	**151**	*	*

* The average of the yields on plots 6a and 6b is here taken at 100 for comparison.

TABLE 42.

SPECIAL NITROGEN EXPERIMENTS ON WHITE FLINT CORN (SERIES F).

Percentages and pounds per acre of dry matter and of protein in stover.

No. of Plot.	FERTILIZERS.	Weight of fertilizer.	Year.	Weight at harvest per acre.	Dry matter.		Protein in dry matter. N. × 6.25.		Percentage of yield on basis of yield from mineral plots. Dry matter.	Percentage of yield on basis of yield from mineral plots. Protein.
		Lbs.		Lbs.	%	Lbs.	%	Lbs	%	%
			1898	805	76.5	616	5.80	36	48	54
0	Nothing, - - - - -	—	1899	1190	72.7	865	8.56	74	50	64
			Av.	**998**	**74.6**	**741**	**7.18**	**55**	**49**	**60**
			1898	1350	72.9	984	5.17	51	76	77
7	{ Mixed Minerals, as No. 6*a*,	480	1899	2675	61.2	1637	8.12	133	95	114
	{ Nitrate of Soda (25 lbs. N.),	160	Av.	**2013**	**67.1**	**1311**	**6.65**	**92**	**87**	**100**
			1898	2210	73.6	1627	5.57	91	126	137
8	{ Mixed Minerals, as No. 6*a*,	480	1899	2750	69.9	1922	8.69	167	112	143
	{ Nitrate of Soda (50 lbs. N.),	320	Av.	**2480**	**71.8**	**1775**	**7.13**	**129**	**118**	**140**
			1898	2070	63.6	1317	6.62	87	102	131
9	{ Mixed Minerals, as No. 6*a*,	480	1899	2550	61.2	1561	11.31	177	91	152
	{ Nitrate of Soda (75 lbs. N.),	480	Av.	**2310**	**62.4**	**1439**	**8.97**	**132**	**95**	**143**
			1898	1790	70.9	1269	5.35	68	*	*
6*a*	{ Dis. Bone-black, } Mixed	320	1899	2600	64.3	1672	7.50	125	*	*
	{ Mur. of Potash, } Min'ls,	160	Av.	**2195**	**67.6**	**1471**	**6.43**	**97**	*	*
			1898	2025	73.3	1484	4.67	69	115	104
10	{ Mixed Minerals, as No. 6*a*,	480	1899	2900	65.2	1891	7.38	140	110	120
	{ Sulph. of Am. (25 lbs. N.),	120	Av.	**2463**	**69.3**	**1688**	**6.03**	**105**	**112**	**114**
			1898	2225	66.9	1489	5.08	76	115	114
11	{ Mixed Minerals, as No. 6*a*,	480	1899	2650	65.8	1744	12.69	221	101	190
	{ Sulph. of Am. (50 lbs. N.),	240	Av.	**2438**	**66.4**	**1617**	**8.89**	**149**	**107**	**162**
			1898	1890	70.9	1340	5.55	74	104	111
12	{ Mixed Minerals, as No. 6*a*,	480	1899	2100	63.6	1336	14.75	197	78	169
	{ Sulph. of Am. (75 lbs. N.),	360	Av.	**1995**	**67.3**	**1338**	**10.15**	**136**	**89**	**148**
			1898	735	70.0	515	8.30	43	40	65
00	Nothing, - - - - -	—	1899	875	71.9	629	10.37	65	37	56
			Av.	**805**	**71.0**	**572**	**9.34**	**54**	**38**	**59**
			1898	1850	71.3	1319	4.89	65	*	*
6*b*	Mixed Minerals, as No. 6*a*,	480	1899	2625	67.6	1775	6.06	108	*	*
			Av.	**2238**	**69.5**	**1547**	**5.48**	**87**	*	*

* The average of the yields on plots 6*a* and 6*b* is here taken at 100 for comparison.

In comparing the results of the experiments for 1898 with those for 1899, it will be noticed that in 1898 the increase in the percentages of protein in the crops which might be ascribed to an increase in the nitrogen in the fertilizer was much less noticeable, on the whole, and corresponded much less regularly with the increase in the quantities of nitrogen used than was the case in 1899. This may be due in part to exceptionally heavy rains in July and August,* 1898, which seemed to curtail the yields and may also have modified the effects of nitrogen on the protein of the crop. As suggested in a preceding paragraph, excessive rain during the growing season may cause considerable of the nitrogen in soluble materials, as nitrates, etc., to be washed away in drainage water, and by thus reducing the amount of nitrogen available to the plants may modify the effect upon both the yield and the composition of the crop.

EXPERIMENTS WITH COW PEAS.

From the diagram on page 172, which illustrates the method of dividing each of the plots in the experimental field into six equal sections one-fiftieth of an acre in size, and shows what crop is grown on each section, it will be seen that cow peas are grown on the two series of sections lettered C and D. The kinds and amounts of fertilizer used on each plot are shown in the diagram on page 170.

The Clay variety of cow peas are used in these experiments. The seed is obtained each year from Tennessee, because it has been found that in this climate cow peas do not mature sufficiently to use the seed grown in the experiments of one year for planting the following year. On the two series of sections, C and D, the cow peas are planted in drills at the rate of about forty quarts per acre. Although the two series of sections are kept separate in growing the crops, the data from both are combined and the results of the experiments are given as if obtained from one series of sections, each one-twenty-fifth of an acre in size.

The results of the experiments for 1897, 1898, and 1899 are given in Tables 43 and 44 which follow. The weights at harvest of the crops on the different sections are given per section and per acre in Table 43; but the figures for the 1897

* See Meteorological observations on p. 245 of the Report for 1898.

experiments are not included in the averages in the table because of the irregularity of the experiments of that year, as above explained. Table 44 gives the percentages and amounts of dry matter in the crop at harvest, and of protein in the dry matter. The analyses for 1897 are also given in this table, but are not included in the averages. These are the only analyses made of any of the crops grown in the special nitrogen experiments of 1897.

The amounts of nitrogen in the fertilizers and the total yields of the crop.—The results of the special nitrogen experiments in their bearing upon the effect of the different fertilizers upon the total yield of the crop are shown in the figures in Table 43. From these figures it will be seen that the yields from all the fertilized plots are about twice as large as those from the plots with no fertilizer. The most noticeable feature of these results is the large yields from the sections of the plots (6*a* and 6*b*), with the mineral fertilizers only, as compared with the yields from the sections of plots having the nitrogenous fertilizers in addition to the minerals. The average of the yields from the sections of the two mineral plots is larger than the yield from either one of a number of the sections of plots with nitrogen. Even where an increase in yield accompanies the application of the nitrogenous fertilizers, the amount of increase does not correspond at all with the quantities of nitrogen used. For instance, in the experiments of both 1898 and 1899, the yield from the sections of plot 7 of the nitrate of soda group, with twenty-five pounds of nitrogen per acre, was larger than that from the sections of either plot 8 or 9 of the same group, with fifty and seventy-five pounds per acre respectively, or from sections of the plots—10, 11, and 12—of the sulphate of ammonia group. The inference from these results is that, so far as the growth of the plants is concerned, good returns follow the application of the mineral fertilizers upon cow peas, but the application of nitrogen has little effect upon the yield.

In the experiments of 1898 the total yield of this crop from the sulphate of ammonia group of plots was practically the same as that from the nitrate of soda group. In the 1899 experiments, however, and in all other experiments with this crop during the past five years, except those of 1898, the yields of cow pea fodder were, on the whole, smaller from the sulphate of ammonia group than from the nitrate of soda group.

Table 43.

SPECIAL NITROGEN EXPERIMENTS ON COW PEA FODDER.

Weight and cost of fertilizers per acre, total crop, and increase of crop over that of the nothing plots.

No. of Plot.	Fertilzers.	Weight of fertilizer.	Year.	Cost of fertilizer.	Yield per section. .1-25 acre.	Yield per acre as harvested.		Gain over nothing plots.
		Lbs.		$	Lbs.	Lbs.	Tons	Lbs.
			1897	—	392	9800	4.9	—
0	Nothing, - - - - -	—	1898	—	456	11400	5.7	—
			1899	—	430	10750	5.4	—
			Av.*	—	**443**	**11075**	**5.6**	—
			1897	10.11	814	20350	10.2	12200
7	Mixed Minerals, as No. 6*a*, -	480	1898	9.37	958	23950	12.0	13450
	Nitrate of Soda (25 lbs. N.), -	160	1899	9.00	910	22750	11.4	13187
			Av.*	—	**934**	**23350**	**11.7**	**13319**
			1897	13.61	766	19150	9.6	11000
8	Mixed Minerals, as No. 6*a*, -	480	1898	12.87	886	22150	11.2	11650
	Nitrate of Soda (50 lbs. N.), -	320	1899	12.13	875	21875	10.9	12312
			Av.*	—	**881**	**22013**	**11.1**	**11981**
			1897	17.11	676	16900	8.5	8750
9	Mixed Minerals, as No. 6*a*, -	480	1898	16.37	930	23250	11.6	12750
	Nitrate of Soda (75 lbs. N.), -	480	1899	15.26	852	21300	10.7	11737
			Av.*	—	**891**	**22275**	**11.2**	**12244**
			1897	6.61	822	20550	10.3	12400
6*a*	Dis. Bone-black, } Mixed	320	1898	5.87	922	23050	11.5	12550
	Mur. of Potash, } Minerals,	160	1899	5.87	850	21250	10.6	11687
			Av.*	—	**886**	**22150**	**11.1**	**12119**
			1897	9.99	692	17300	8.7	9150
10	Mixed Minerals, as No. 6*a*, -	480	1898	9.37	906	22650	11.3	12150
	Sulph. of Am. (25 lbs. N.), -	120	1899	9.62	845	21125	10.6	11562
			Av.*	—	**876**	**21888**	**11.0**	**11856**
			1897	13.37	666	16650	8.3	8500
11	Mixed Minerals, as No. 6*a*, -	480	1898	12.87	934	23350	11.7	12850
	Sulph. of Am. (50 lbs. N.), -	240	1899	13.37	765	19125	9.6	9562
			Av.*	—	**850**	**21238**	**10.7**	**11206**
			1897	16.75	604	15100	7.6	6950
12	Mixed Minerals, as No. 6*a*, -	480	1898	16.37	926	23150	11.6	12650
	Sulph. of Am. (75 lbs. N.), -	360	1899	17.12	770	19250	9.6	9687
			Av.*	—	**848**	**21200**	**10.6**	**11169**
			1897	—	260	6500	3.3	—
00	Nothing, - - - - -	—	1898	—	384	9600	4.8	—
			1899	—	335	8375	4.2	—
			Av.*	—	**360**	**8988**	**4.5**	—
			1897	6.61	744	18600	9.3	10450
6*b*	Mixed Minerals, as No. 6*a*, -	480	1898	5.87	880	22000	11.0	11500
			1899	5.87	893	22325	11.2	12762
			Av.*	—	**887**	**22163**	**11.1**	**12131**

* Average omitting 1897.

In the case of corn, in which similar results have been noted, the smaller yield with the sulphate has been explained as possibly due to an acidity of soil resulting from the repeated application of this material to the same plots year after year. The exception in 1898 noted above may, perhaps, be the result of the exceptional rainfall of 1897, and heavy rains also in 1898, which may have washed considerable of the surplus acid out of the soil at that time. No experiments have been made by the Station to test the advantages of lime upon the sections of the sulphate of ammonia plots upon which cow peas are grown.

The amounts of nitrogen in the fertilizers and the proportions of protein in the crop.—From Table 44 below, giving the percentages and amounts of dry matter in the crop at harvest and the percentages and amounts of protein in the dry matter, it will be seen that in many instances the percentages of protein are larger in the crops from sections of plots without fertilizers than in those from sections of plots with fertilizers. This has been noticed in the case of corn also, and may, perhaps, be due to premature ripening of the plants on the sections without fertilizer. It has been shown by analyses that the proportion of protein is larger in immature, or "poor" corn, than in mature, or "good" corn.

From the results given in Table 44 there appears to be but little relationship between the quantity of nitrogen in the fertilizer and the proportion of protein in the crop. In the 1898 experiments the percentage of protein was higher in the average of the crops from the sections of the two mineral plots than in the crop from sections of any of the plots with nitrogen. In the 1899 experiments, however, there appeared to be some increase in the proportion of protein in the crop accompanying the increase in the nitrogen in the fertilizer, as may be seen by comparing with each other the percentages of protein in the crops from sections of plots 7, 8, and 9, with respectively 25, 50, and 75 pounds of nitrogen in nitrate of soda, and also those from sections of plots 10, 11, and 12, with like amounts of nitrogen in sulphate of ammonia. In the experiments with cow peas, as a whole, the increase in the protein in the crop which accompanies the application of the nitrogen in the fertilizers, as shown by figures for percentages and yields of protein per acre, has been smaller and less uniform than in the experiments with common grasses.

Table 44.

SPECIAL NITROGEN EXPERIMENTS ON COW PEA FODDER.

Percentages and pounds per acre of dry matter and of protein.

No. of Plot.	Fertilizers.	Weight of fertilizer.	Year.	Weight at harvest per acre.	Dry matter.		Protein in dry matter. N. × 6.25.		Percentage of yield on basis of yield from mineral plots. Dry matter.	Pro-tein.
		Lbs.		Lbs.	%	Lbs.	%	Lbs.	%	%
0	Nothing,	—	1897	9800	18.5	1813	21.69	393	56	65
			1898	11400	18.9	2155	16.26	350	58	50
			1899	10750	16.3	1752	20.81	365	54	55
			Av.*	**11075**	**17.6**	**1954**	**18.54**	**358**	**56**	**56**
7	Mixed Minerals, as No. 6*a*, Nitrate of Soda (25 lbs. N.),	480 160	1897	20350	17.8	3622	17.68	640	112	106
			1898	23950	18.1	4335	16.38	710	116	101
			1899	22750	14.8	3367	21.06	709	104	106
			Av.*	**23350**	**16.5**	**3851**	**18.72**	**710**	**110**	**112**
8	Mixed Minerals, as No. 6*a*, Nitrate of Soda (50 lbs. N.),	480 320	1897	19150	17.8	3409	19.03	649	106	107
			1898	22150	17.5	3876	16.91	655	104	93
			1899	21875	15.2	3325	19.69	655	103	98
			Av.*	**22013**	**16.4**	**3601**	**18.30**	**655**	**103**	**103**
9	Mixed Minerals, as No. 6*a*, Nitrate of Soda (75 lbs. N.),	480 480	1897	16900	17.1	2890	18.43	533	90	88
			1898	23250	18.6	4325	17.51	757	116	108
			1899	21300	14.8	3152	22.94	723	97	108
			Av.*	**22275**	**16.7**	**3739**	**20.23**	**740**	**107**	**117**
6*a*	Dis. Bone-black, Mur. of Potash, Mixed Min.,	320 160	1897	20550	16.2	3329	19.25	641	†	†
			1898	23050	17.3	3988	17.98	717	†	†
			1899	21250	15.0	3188	21.12	673	†	†
			Av.*	**22150**	**16.2**	**3588**	**19.55**	**695**	†	†
10	Mixed Minerals, as No. 6*a*, Sulph. of Am. (25 lbs. N.),	480 120	1897	17300	16.5	2855	18.43	526	88	87
			1898	22650	17.9	4055	16.82	682	108	97
			1899	21125	15.7	3317	20.07	666	103	100
			Av.*	**21888**	**16.8**	**3686**	**18.45**	**674**	**106**	**106**
11	Mixed Minerals, as No. 6*a*, Sulph. of Am. (50 lbs. N.),	480 240	1897	16650	17.2	2864	15.91	456	89	75
			1898	23350	17.0	3970	17.99	714	106	102
			1899	19125	15.3	2926	20.88	611	90	91
			Av.*	**21238**	**16.2**	**3448**	**19.44**	**663**	**99**	**104**
12	Mixed Minerals, as No. 6*a*, Sulph. of Am. (75 lbs. N.),	480 360	1897	15100	18.0	2718	22.79	619	84	102
			1898	23150	16.8	3889	17.03	662	104	94
			1899	19250	14.2	2734	22.94	627	85	94
			Av.*	**21200**	**15.5**	**3312**	**19.99**	**645**	**95**	**102**
00	Nothing,	—	1897	6500	18.9	1229	18.13	223	38	37
			1898	9600	18.9	1814	17.87	324	48	46
			1899	8375	16.2	1357	23.31	316	42	47
			Av.*	**8988**	**17.6**	**1586**	**20.59**	**320**	**45**	**50**
6*b*	Mixed Minerals, as No. 6*a*,	480	1897	18600	16.8	3125	18.17	568	†	†
			1898	22000	15.9	3498	19.57	685	†	†
			1899	22325	14.7	3282	20.19	663	†	†
			Av.*	**22163**	**15.3**	**3390**	**19.88**	**674**	†	†

* Average omitting 1897.

† The average of the yields on plots 6*a* and 6*b* is here taken at 100 for comparison.

EXPERIMENTS WITH SOY BEANS.

As seen by the diagram on page 172 soy beans are grown upon the two series of sections lettered B and E. In the experiments with this crop, as in those with cow peas, the two series are used for growing the crops, but the results obtained on both are combined and reported as if only one series of sections twice the size were used. The results of the experiments with this crop are given in Tables 45 and 46 following. The experiments with this crop in 1896 are also included here, inasmuch as they have not been reported previously. The averages in the tables, therefore, include the results of three years—1896, 1898, and 1899—instead of two as in the case of corn and cow peas. The weights of the yields for 1897 are given in Table 45, but, as previously explained, they are not included in the averages nor considered in the discussion.

In these experiments with soy beans only the seed is taken into account. No attempt was made to estimate the yields of the vines after the seed was removed, because by the time the seed is well matured nearly all of the leaves have fallen from the vines.

The amounts of nitrogen in the fertilizers and the total yield of the crop.—The results of the experiments as regards the yields of the crop, given in Table 45 below, show that in many cases the yields from sections of plots with mineral fertilizers only were smaller than from sections of plots with nitrogen in addition to the minerals. The differences, on the whole, are more noticeable in the experiments with soy beans than in those with cow peas, suggesting that probably the nitrogenous fertilizers had more effect in increasing the yields of the soy beans. The total increase in the yields, however, accompanying the increase in the nitrogen of the fertilizer, did not correspond with the amounts of nitrogen used. In the experiments with soy beans here reported, in no case was the yield largest from the section of the plot with the largest quantity of nitrogen in the nitrate of soda group, and only in one case in the sulphate of ammonia group. The largest yields, on the average, were generally obtained from sections of plots with nitrogen at fifty pounds per acre. The value of the increase, however, which might be attributed to the nitrogenous fertilizers, was not sufficient in most cases to cover the cost of the nitrogen added to the mineral fertilizers.

Table 45.

SPECIAL NITROGEN EXPERIMENTS ON SOY BEAN SEED.

Weight and cost of fertilizers per acre, total crop, and increase of crop over that of the nothing plots.

No. of Plot.	Fertilizers.	Weight of fertilizer.	Year.	Cost of fertilizer.	Yield per section. 1-25 acre.	Yield per acre.		Gain over nothing plots.
		Lbs.		$	Lbs.	Lbs.	Bu.	Bu.
0	Nothing,	—	1896	—	23.6	590	9.8	—
			1897	—	9.0	225	3.8	—
			1898	—	19.6	490	8.2	—
			1899	—	30.2	755	12.6	—
			Av.*	—	**24.5**	**61.2**	**10.2**	—
7	Mixed Minerals, as No. 6*a*,	480	1896	9.99	39.9	998	16.6	5.5
	Nitrate of Soda (25 lbs. N.),	160	1897	10.11	23.6	590	9.8	6.1
			1898	9.37	33.6	840	14.0	5.9
			1899	9.00	42.8	1070	17.8	5.7
			Av.*	—	**38.8**	**969**	**16.1**	**5.7**
8	Mixed Minerals, as No. 6*a*,	480	1896	13.37	41.8	1045	17.4	6.3
	Nitrate of Soda (50 lbs. N.),	320	1897	13.61	13.9	348	5.8	2.1
			1898	12.87	40.1	1003	16.7	8.6
			1899	12.13	48.8	1220	20.3	8.2
			Av.*	—	**43.6**	**1089**	**18.1**	**7.7**
9	Mixed Minerals, as No. 6*a*,	480	1896	16.75	40.4	1010	16.8	5.7
	Nitrate of Soda (75 lbs. N.),	480	1897	17.11	17.6	440	7.3	3.6
			1898	16.37	36.2	905	15.1	7.0
			1899	15.26	48.7	1218	20.3	8.2
			Av.*	—	**41.8**	**1044**	**17.4**	**7.0**
6*a*	Dis. Bone-black, } Mixed	320	1896	6.61	37.4	935	15.6	4.5
	Mur. of Potash, } Minerals,	160	1897	6.61	11.4	285	4.8	1.1
			1898	5.87	31.5	788	13.1	5.0
			1899	5.87	38.4	960	16.0	3.9
			Av.*	—	**35.8**	**894**	**14.9**	**4.5**
10	Mixed Minerals, as No. 6*a*,	480	1896	10.36	38.6	965	16.1	5.0
	Sulph. of Am. (25 lbs. N.),	120	1897	9.99	8.6	215	3.6	.1
			1898	9.37	30.4	760	12.7	4.6
			1899	9.62	41.7	1043	17.4	5.3
			Av.*	—	**36.9**	**923**	**15.4**	**5.0**
11	Mixed Minerals, as No. 6*a*,	480	1896	14.11	38.8	970	16.2	5.1
	Sulph. of Am. (50 lbs. N.),	240	1897	13.37	15.4	385	6.4	2.7
			1898	12.87	36.0	900	15.0	6.9
			1899	13.37	43.9	1098	18.3	6.2
			Av.*	—	**39.6**	**989**	**16.5**	**6.1**
12	Mixed Minerals, as No. 6*a*,	480	1896	17.86	42.0	1050	17.5	6.4
	Sulph. of Am. (75 lbs. N.),	360	1897	16.75	17.0	425	7.1	3.4
			1898	16.37	35.2	880	14.7	6.6
			1899	17.12	43.3	1083	18.1	6.0
			Av.*	—	**40.2**	**1004**	**16.8**	**6.3**

* Average omitting 1897.

TABLE 45.—*(Continued.)*

No. of Plot.	FERTILIZERS.	Weight of fertilizer.	Year.	Cost of fertilizer.	Yield per section. 1-25 acre.	Yield per acre.		Gain over nothing plots.
		Lbs.		$	Lbs.	Lbs.	Bu.	Bu.
00	Nothing,	—	1896	—	28.0	750	12.5	—
			1897	—	8.4	210	3.5	—
			1898	—	19.2	480	8.0	—
			1899	—	27.5	688	11.5	—
			Av.*	—	**24.9**	**639**	**10.7**	—
6*b*	Mixed Minerals, as No. 6*a*,	480	1896	6.61	36.9	923	15.4	4.3
			1897	6.61	14.9	373	6.2	2.5
			1898	5.87	38.7	968	16.1	8.0
			1899	5.87	44.7	1118	18.6	6.5
			Av.*	—	**40.1**	**1003**	**16.7**	**6.3**

* Average omitting 1897.

The amounts of nitrogen in the fertilizers and the proportion of protein in the crop.—As seen by the figures in Table 46 below, the percentage of protein in the crop from the plots with minerals only is in some cases smaller and in others larger than in the crop from the sections of plots with nitrogen in addition to the minerals. The average of the yields from the sections of both the mineral plots is somewhat smaller than the average yield from any of the sections of plots with nitrogen; but because of the irregularity in this respect it can hardly be said that a lack of nitrogen in the fertilizer was accompanied by a smaller percentage of protein in the crop. In the crops from the sections of plots with the nitrogenous fertilizers, in the experiments of 1896 and 1899, the percentage of protein was largest where the largest quantities of nitrogen were used. The experiments of 1898, as has been suggested in the discussion of experiments with other crops, may have been modified by heavy rains in the growing season.

It will be observed from the figures in Table 46, that not only the percentage of protein in the crop, but also the total yields of protein per acre were largest in several cases where the largest quantities of nitrogen were used in the fertilizers. On the whole, the experiments with this crop seem to indicate that the nitrogenous fertilizers tend to increase the yields of dry matter and of protein more than was found in the experiments with cow peas, but the increase does not correspond with the amounts of nitrogen used.

TABLE 46.

SPECIAL NITROGEN EXPERIMENTS ON SOY BEAN SEED.

Percentages and pounds per acre of dry matter and of protein.

No. of Plot.	FERTILIZERS.	Weight of fertilizer.	Year.	Weight at harvest per acre.	Dry matter.		Protein in dry matter. N. × 6.25.		Percentage of yield on basis of yield from mineral plots.	
									Dry matter.	Protein.
		Lbs.		Lbs.	%	Lbs.	%	Lbs.	%	%
0	Nothing, - - - -	—	1896	590	94.5	558	38.14	213	63	63
			1898	490	93.2	457	44.21	202	57	60
			1899	755	90.8	686	42.50	292	71	76
			Av.	**612**	**92.8**	**567**	**41.62**	**236**	**64**	**66**
7	Mixed Minerals, as No. 6*a*,	480	1896	998	96.3	961	37.58	361	109	106
	Nitrate of Soda (25 lbs. N.),	160	1898	840	90.9	764	44.91	343	96	101
			1899	1070	91.8	982	40.57	398	102	103
			Av.	**969**	**93.0**	**902**	**41.02**	**367**	**102**	**103**
8	Mixed Minerals, as No. 6*a*,	480	1896	1045	96.4	1007	38.00	383	114	112
	Nitrate of Soda (50 lbs. N.),	320	1898	1003	91.4	917	44.77	411	115	121
			1899	1220	92.6	1130	40.06	453	117	117
			Av.	**1089**	**93.5**	**1018**	**40.94**	**416**	**115**	**117**
9	Mixed Minerals, as No. 6*a*,	480	1896	1010	96.2	972	38.09	370	110	109
	Nitrate of Soda (75 lbs. N.),	480	1898	905	91.0	824	44.40	366	103	108
			1899	1218	91.7	1117	41.31	461	116	119
			Av.	**1044**	**93.0**	**971**	**41.27**	**399**	**110**	**112**
6*a*	Dis. Bone-black, } Mixed	320	1896	935	95.1	889	38.32	341	†	†
	Mur. of Potash, } Min.,	160	1898	788	91.8	723	42.23	305	†	†
			1899	960	92.2	885	41.57	368	†	†
			Av.	**894**	**93.0**	**832**	**40.71**	**338**	†	†
10	Mixed Minerals, as No. 6*a*,	480	1896	965	97.2	938	41.45	389	106	114
	Sulph. of Am. (25 lbs. N.),	120	1898	760	90.7	689	41.64	387	86	114
			1899	1043	91.2	951	40.94	389	99	101
			Av.	**923**	**93.0**	**859**	**41.34**	**355**	**97**	**100**
11	Mixed Minerals, as No. 6*a*,	480	1896	970	96.3	934	41.93	392	106	115
	Sulph. of Am. (50 lbs. N.),	240	1898	900	90.5	815	42.54	347	102	102
			1899	1098	91.6	1006	40.88	411	105	106
			Av.	**989**	**92.8**	**918**	**41.78**	**383**	**104**	**108**
12	Mixed Minerals, as No. 6*a*,	480	1896	1050	95.4	1002	42.12	422	113	124
	Sulph. of Am. (75 lbs. N.),	360	1898	880	90.7	798	42.05	336	100	99
			1899	1083	91.7	993	43.25	420	103	109
			Av.	**1004**	**92.6**	**931**	**42.47**	**396**	**106**	**111**
00	Nothing, - - - -	—	1896	750	95.0	713	37.27	266	81	78
			1898	480	91.6	440	45.65	201	55	59
			1899	688	90.6	623	47.06	293	65	76
			Av.	**639**	**92.4**	**592**	**43.33**	**253**	**67**	**71**
6*b*	Mixed Minerals, as No. 6*a*,	480	1896	923	95.5	881	38.55	340	†	†
			1898	968	90.6	877	42.64	374	†	†
			1899	1118	92.9	1039	38.94	405	†	†
			Av.	**1003**	**93.0**	932	**40.04**	**373**	†	†

† The average of the yields on plots 6*a* and 6*b* is here taken at 100 for comparison.

SOIL TEST EXPERIMENTS.

In 1890 the Station began at Storrs, on the same field as that used for the special nitrogen experiments, a series of experiments known as "soil tests." The purpose was to study the deficiencies of soils and the particular needs of different crops for the different ingredients of fertilizers. The fertilizers used in these soil tests are, in general, of the same kinds of materials—dissolved bone-black, muriate of potash, and nitrate of soda—as those used in the special nitrogen experiments, and supply the phosphorus, potash, and nitrogen in the same combinations. In the special nitrogen experiments a uniform mixture of the mineral fertilizers—super-phosphate and potash salt—is used as a basis, and to this nitrogen is added in increasing proportions. In the soil test experiments the phosphoric acid, potash, and nitrogen are applied upon parallel plots of land first singly, then two by two, and finally all three together, as shown in the diagram on page 198.

For this series of soil test experiments a double group of plots was arranged as explained in the following paragraph, and upon these the experiments have been continued year by year, with the same plots and the same kinds and amounts of fertilizers on each indicated in the diagram below. The crops used in these experiments were grown in the following rotation, beginning with 1890: corn, potatoes, oats, cow peas, corn, potatoes, oats, soy beans, corn, potatoes. The experiments of 1897, 1898, and 1899, here reported, are the eighth, ninth, and tenth of this series, the crops grown in those years being respectively soy beans, corn, potatoes. The results of experiments previous to these are given in the annual Reports of the Station up to and including 1896.

The method of dividing the field into plots for these experiments, and the kinds of fertilizers and the amounts per acre used on each plot, are illustrated by the following diagram. The plots are laid out with the long dimension north and south. The field slopes gently to the south, but with not enough incline to cause serious washing and cutting of the surface by water. The soil of the field is a heavy loam, with a yellow clay loam subsoil. In 1888 and 1889, when the field was being cropped preparatory to being laid out for this series of experiments, it was noticed that the soil seemed to be poorer

toward the west side of the field. For this reason the field was divided into two sets of plots, each one-twenty-fourth acre in size, and the order of the plots in one of the two sets was reversed, as shown in the diagram. In considering the results of the experiments the data from both plots of the same number are combined and the results considered as if obtained from one plot one-twelfth acre in size. In this way errors due to the irregularities of the soil are partially eliminated.

Diagram illustrating the arrangement of the plots in the soil test, and the kinds of fertilizers and amounts per acre used on each plot.

Unfertilized strips separate the adjoining plots.

EAST.

NORTH. | SOUTH.

Plot o. Nothing.	Plot Y. Stable manure, 16000 lbs.
Plot A. Nit. of Soda, 160 lbs.	Plot X. { Stable man., 10000 lbs. Dis. Bone-bl'k, 160 lbs.
Plot B. Dis. Bone-bl'k, 320 lbs.	Plot ooo. Nothing.
Plot C. Mur. of Pot., 160 lbs.	Plot G. { Dis. Bone-bl'k, 320 lbs. Mur. of Pot., 160 lbs. Nit. of Soda, 160 lbs.
Plot oo. Nothing.	Plot F. { Dis. Bone-bl'k, 320 lbs. Mur. of Pot., 160 lbs.
Plot D. { Dis. Bone-bl'k, 320 lbs. Nit. of Soda, 160 lbs.	Plot E. { Mur. of Pot., 160 lbs. Nit. of Soda, 160 lbs.
Plot E. { Mur. of Pot., 160 lbs. Nit. of Soda, 160 lbs.	Plot D. { Dis. Bone-bl'k, 320 lbs. Nit. of Soda, 160 lbs.
Plot F. { Dis. Bone-bl'k, 320 lbs. Mur. of Pot., 160 lbs.	Plot oo. Nothing.
Plot G. { Dis. Bone-bl'k, 320 lbs. Mur. of Pot., 160 lbs. Nit. of Soda, 160 lbs.	Plot C. Mur. of Pot., 160 lbs.
Plot ooo. Nothing.	Plot B. Dis. Bone-bl'k, 320 lbs.
Plot X. { Stable manure, 1000 lbs. Dis. Bone-bl'k, 160 lbs.	Plot A. Nit. of Soda, 160 lbs.
Plot Y. Stable manure, 16000 lbs.	Plot o. Nothing.

WEST.

In addition to the plots in the regular soil test, which include the plots from o to ooo inclusive in the above diagram, and are treated with the commercial fertilizers as explained, two other plots, X and Y, of the same size are included in the series, the former being treated with stable manure and phosphoric acid, and the latter with a larger quantity of stable manure, but without the addition of the mineral fertilizer.

Experiment of 1897.—From the rotation of crops given above it will be seen that soy beans were planted in 1897 following oats in 1896, instead of cow peas which had previously succeeded oats in the order of rotation. The results of the experiments with this crop are given in Table 47 below. The season was so wet, as before explained, that the field experiments were spoiled. The experiments for 1897, therefore, are not discussed.

TABLE 47.

SOIL TEST WITH FERTILIZERS ON SOY BEANS.

BY THE STATION, STORRS, 1897.

No. of Plot.	Fertilizers per Acre. Kind.	Weight.	Cost.	Yield per plot. 1-12 acre.	Yield per acre.		Gain over nothing plots.
		Lbs.	$	Lbs.	Lbs.	Bu.	Bu.
o	Nothing,	—	—	34.0	408	6.8	—
A	Nitrate of Soda,	160	3.50	31.0	372	6.2	−1.0
B	Dis. Bone-black,	320	2.92	35.5	426	7.1	−.1
C	Muriate of Potash,	160	3.69	31.9	383	6.4	−.8
oo	Nothing,	—	—	35.5	426	7.1	—
D	Nitrate of Soda,	160	6.42	44.8	538	9.0	1.8
	Dis. Bone-black,	320					
E	Nitrate of Soda,	160	7.19	37.9	455	7.6	.4
	Muriate of Potash,	160					
F	Dis. Bone-black,	320	6.61	46.7	560	9.3	2.1
	Muriate of Potash,	160					
G	Nitrate of Soda,	160	10.11	43.1	517	8.6	1.4
	Dis. Bone-black,	320					
	Muriate of Potash,	160					
ooo	Nothing,	—	—	38.5	462	7.7	—
X	Stable manure,	†10000	8.12*	57.3	688	11.5	4.3
	Dis. Bone-black,	160					
Y	Stable manure,	‡16000	10.68*	63.7	764	12.7	5.5

* The manure was valued at $3 per cord of 4,500 pounds. † Equivalent to 2.22 cords. ‡ Equivalent to 3.56 cords.

Experiments of 1898.—The soil test of 1898 was made with corn and seemed to be normal throughout, although the growing season of this year, while not so wet as that of 1897, was somewhat wetter than the average, owing to heavy rains in July and August. Quite a marked difference in the growth on

the different plots manifested itself throughout the season. In general the crops on the plots having no nitrogen in the fertilizer were pale yellow in color and more backward in growth than those on the plots with nitrogen. A comparison of the results from plot D with those from plots E and F, as given in Table 48 below, suggests that in this particular experiment the corn seemed to be benefited most by the combination of nitrogen and phosphoric acid in the fertilizer. The table shows, however, that the largest yields of corn in 1898 were obtained from plots X and Y, which had the stable manure with and without phosphoric acid. This is the third time that corn has come into the rotation of crops in this series of experiments; and, as will be seen by comparing the results for the three years, given in Table 50, in two of the three years the largest yield has been obtained from plot Y, with the largest amount of stable manure, while in the other year the yield from this plot was essentially the same as that from the plot G, with the mixed minerals and nitrogen.

TABLE 48.

SOIL TEST WITH FERTILIZERS ON WHITE FLINT CORN.

By the Station, Storrs, 1898.

No. of Plot.	Fertilizers per Acre.			Yield per Plot. 1-12 Acre.			Yield per Acre.			
	Kind.	Weight.	Cost.	Total ears.	Shelled corn.	Stover.	Shelled corn.	Shelled corn.	Stover.	Gain over not'g plots.
		Lbs.	$	Lbs.	Lbs.	Lbs	Lbs.	Bu.	Lbs.	Bu.
0	Nothing, - -	—	—	129.0	110.0	81	1320	23.6	972	—
A	Nit. of Soda, -	160	3.50	151.0	128.0	91	1536	27.4	1092	7.6
B	Dis. Bone-black,	320	2.39	147.5	128.0	95	1536	27.4	1140	7.6
C	Mur. of Potash, -	160	3.48	117.0	100.0	110	1200	21.4	1320	1.6
00	Nothing, - -	—	—	94.0	78.5	72	942	16.8	864	—
D	Nit. of Soda, - Dis. Bone-black,	160 320	5.89	184.0	156.0	128	1872	33.4	1536	13.6
E	Nit. of Soda, - Mur. of Potash, -	160 160	6.98	160.0	138.0	125	1656	29.6	1500	9.8
F	Dis. Bone-black, Mur. of Potash, -	320 160	5.87	134.5	112.0	153	1344	24.0	1836	4.2
G	Nit. of Soda, - Dis. Bone-black, Mur. of Potash, -	160 320 160	9.37	194.0	165.0	159	1980	35.4	1908	15.6
000	Nothing, - -	—	—	104.0	88.5	91	1062	19.0	1092	—
X	Stable manure, - Dis. Bone-black,	†10000 160	7.85*	216.5	188.0	155	2256	40.3	1860	20.5
Y	Stable manure, -	‡16000	10.68*	235.0	201.0	185	2412	43.1	2220	23.3

* The manure was valued at $3 per cord of 4,500 pounds. † Equivalent to 2.22 cords.
‡ Equivalent to 3.56 cords.

Experiments of 1899.—Potatoes were grown in the soil tests of 1899. This is the third time this crop has been grown in this series of experiments. Two early varieties of potatoes were planted: "Fortune" on the set of plots on the north side of the field, and "Queen" on the set on the south side. In the early part of the season all the plants made a "full stand" and a fairly even growth; but, as the season advanced, quite striking differences were noticed in the growth on the different plots. Throughout the latter half of the season there was a healthier and more vigorous growth of plants on the plots upon which potash was applied. The beneficial effect of the potash upon this crop in this experiment is indicated by a comparison of the results from plots A, B, and C with each other, and also those from plots D, E, and F, as given in Table 49 below.

TABLE 49.

SOIL TEST WITH FERTILIZERS ON POTATOES.

BY THE STATION, STORRS, 1899.

No. of Plot.	Fertilizers per Acre.			Yield per Plot. 1-12 Acre.			Yield per Acre.			
	Kind.	Weight.	Cost.	Large.	Small.	Total.	Large.	Small.	Total.	Gain over not'g plots.
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Bu.	Bu.
O	Nothing, - -	—	—	121	149	270	24.2	29.8	54.0	—
A	Nit. of Soda, -	160	3.13	67	79	146	13.4	15.8	29.2	-6.8
B	Dis. Bone-black,	320	2.39	70	130	200	14.0	26.0	40.0	4.0
C	Mur. of Potash,	160	3.48	228	99	327	45.6	19.8	65.4	29.4
OO	Nothing, - -	—	—	52	77	129	10.4	15.4	25.8	—
D	Nit. of Soda, - Dis. Bone-black,	160 320	5.52	90	88	178	18.0	17.6	35.6	-.4
E	Nit. of Soda, - Mur. of Potash,	160 160	6.61	345	132	477	69.0	26.4	95.4	59.4
F	Dis. Bone-black, Mur. of Potash,	320 160	5.87	311	171	482	62.2	34.2	96.4	58.4
G	Nit. of Soda, - Dis. Bone-black, Mur. of Potash,	160 320 160	9.00	463	149	612	92.6	29.8	122.4	86.4
OOO	Nothing, - -	—	—	56	85	141	11.2	17.0	28.2	—
X	Stable manure, - Dis. Bone-black,	†10000 160	7.85*	281	160	441	56.2	32.0	88.2	52.2
Y	Stable manure, -	‡16000	10.68*	415	194	609	83.0	38.8	121.8	85.8

* The manure was valued at $3 per cord of 4,500 pounds. † Equivalent to 2.22 cords. ‡ Equivalent to 3.56 cords.

In each case the yield from the plots with potash was very much larger than from those without. The total yields per acre, however, and the proportion of merchantable tubers were largest from plot G, with the complete fertilizer, *i. e.*, nitrogen, phosphoric acid, and potash. It will be seen from Table 50 that for the three years in which this crop has been used in this series of experiments the largest yields have in all cases been obtained from plot G, although the yields have been nearly as large from plot Y, with the largest amount of stable manure.

The results of these experiments for the ten years in which the series has been thus far carried on, with the rotation of crops as stated, are summarized in the following table. They seem to indicate that there is no striking deficiency of any one of the ingredients—nitrogen, phosphoric acid, or potash—in this particular soil. The special requirements for fertilizers, as shown by the results from year to year, seem to be determined more largely by the needs of the particular crop than by the peculiarities of the soil. This fact is illustrated quite clearly by the figures in Table 50.

TABLE 50.

Yields in the Station soil test experiments for the past ten years.

Plot No.	FERTILIZERS.	Weight per acre.	Corn. 1890.	Potatoes. 1891.	Oats. 1892.	Cow peas (vines). 1893.	Corn. 1894.	Potatoes. 1895.	Oats. 1896.	Soy beans. 1897.	Corn. 1898.	Potatoes. 1899.
		Lbs.	Bu.	Bu.	Bu.	Lbs.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
O	Nothing, -	—	28.9	89	29.1	10230	33.6	55	29.6	6.8	23.6	54.0
A	Nit. of Soda,	160	32.4	105	36.0	10960	41.0	50	39.0	6.2	27.4	29.2
B	Dis. Bn.-bl'k,	320	33.3	97	27.0	10710	37.6	56	34.9	7.1	27.4	40.0
C	Mur. of Pot.,	160	30.4	171	26.3	11680	40.8	88	27.8	6.4	21.4	65.4
OO	Nothing, -	—	26.7	87	24.2	9725	28.0	38	26.3	7.1	16.8	25.8
D	Nit. of Soda, Dis. Bn.-bl'k,	160 320	36.1	110	37.9	12920	40.8	57	48.0	9.0	33.4	35.6
E	Nit. of Soda, Mur. of Pot.,	160 160	32.8	160	30.0	13335	47.6	104	41.3	7.6	29.6	95.4
F	Dis. Bn.-bl'k, Mur. of Pot.,	320 160	34.4	214	27.8	15790	48.2	109	36.4	9.3	24.0	96.4
G	Nit. of Soda, Dis. Bn.-bl'k, Mur. of Pot.,	160 320 160	37.4	259	39.4	16210	58.2	129	50.6	8.6	35.4	122.4
OOO	Nothing, -	—	28.5	88	22.5	12100	38.0	49	29.3	7.7	19.0	28.2
X	Stable man., Dis. Bn.-bl'k,	10000 160	44.1	210	40.9	15795	57.0	110	48.8	11.5	40.3	88.2
Y	Stable man.,	16000	43.6	250	41.3	15875	56.7	125	55.1	12.7	43.1	121.8

SUMMARY AND GENERAL DEDUCTIONS.

The special nitrogen experiments here reported were made with corn, cow peas, and soy beans. The purpose of the experiments is twofold: First, to study the effects upon the yields of the crops when different kinds and quantities of nitrogenous fertilizers are used in addition to uniform quantities of mineral fertilizers; and second, to study the effect of the nitrogen in the fertilizers upon the proportion and amount of protein in the crops.

The experiments with corn seem to indicate that mineral fertilizers alone are of comparatively little value for increasing the yields of the crops, while nitrogenous fertilizers with the minerals greatly increase the yields. In considering the yields alone the nitrogenous fertilizers are most profitable on this crop when used in quantities sufficient to supply from twenty-five to fifty pounds of nitrogen per acre, in connection with liberal quantities of phosphoric acid and potash. But when the increased feeding value is also considered, as indicated by the percentages and total yields of protein per acre, even larger quantities of the nitrogenous fertilizers may sometimes prove economical. In these experiments in most cases the largest percentages of protein have been found, in both the corn and stover, from plots where the largest quantities of nitrogen have been used in the fertilizers.

*In contrast with corn, the experiments with legumes indicate that nitrogenous fertilizers increase the yield but very little over that which is obtained from the use of mineral fertilizers only. In the experiments with the cow pea fodder, the average of the results here reported shows essentially no advantage in the use of the nitrogenous fertilizers. The results of the experiments with soy beans grown for seed show some increase from the use of the nitrogenous fertilizers, but the increase was small. As regards the percentages and yields of protein in either cow peas or soy beans the results show very little increase accompanying the increase in the amount of nitrogen in the fertilizers. On the whole, therefore, the experiments appear to indicate that where an abundance of mineral fertilizers are available, nitrogen has very little effect in increasing either the total yield or feeding value of cow peas or soy beans.**

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* A more complete discussion of the effects of nitrogenous fertilizers upon the yields and the composition of certain grasses, grains, and legumes will be found on pp. 113-203 of the Report of this Station for 1898.

From the results of the soil test experiments here reported it appears that, in the case of the soil upon which the experiment was made, the peculiarities of the crop grown in any particular experiment is of more importance than any deficiency of the soil in regulating the demand for fertilizers. During the ten years in which the experiments have been made on the field with a rotation of crops, the ingredient or ingredients that have been most essential have varied with the crop. When corn and oats were grown phosphoric acid and nitrogen appeared to be most essential, while the requirement of potatoes seemed to be potash.

In soil tests made for a number of years by the Station, in coöperation with farmers on farms in different parts of the State, the results in numerous instances have shown that deficiencies in the soil rather than the kind of crop have regulated the demands for fertilizers. Some soils are naturally lacking in some one of the essential ingredients of plant food, but are well supplied with the others; while other soils, like that in experiments at the Station, show no special deficiency in any one of the essential ingredients of plant food, but seem to be lacking in all of them. The particular importance of these results to the farmer is the indication of the need of studying and testing his own soil to learn its deficiencies and peculiar needs.

AN EXPERIMENT ON SOIL IMPROVEMENT.

BY C. S. PHELPS.

An experiment on soil improvement, which is to be continued through quite a period of years, was laid out by the Station on a series of plots of land at Storrs in the spring of 1899. An account of the preliminary experiment is here given. The soil on which the experiment is being carried out appears to be lacking in organic matter and probably in available nitrogen. Such a soil is commonly spoken of as "poor" or "worn out." The purpose of the experiment is to compare the value and economy of different methods of manuring for restoring fertility to a soil of this kind. The fertilizers used in the experiments, the kinds and quantities of which are fully explained in a later paragraph, are (1) stable manure, (2) a "complete" chemical fertilizer, and (3) "green" manures, both alone and in combination with mineral fertilizers. The plan of the experiments, which is given in detail beyond, consists briefly in applying the fertilizers of the different kinds and combinations upon the different plots, growing the same crop on all of the plots, and comparing the results in the yields of the crop.

The field selected for this experiment is one which had been used for a peach orchard since 1889. While the peach trees were growing the field had been liberally treated with mineral fertilizers, but not very much nitrogen had been supplied. During the years 1889 to 1894 different crops had been grown between the rows of trees and had been removed from the land; after 1894 the land remained under cultivation most of the time, but without cropping. Part of the peach trees were removed in the fall of 1897 and the balance in the fall of 1898. When the field was plowed in the spring of 1899 the soil, which is a medium heavy loam and holds moisture well, was compact and hard and seemed to be lacking in organic matter.

Plan of the experiment.—The arrangement of the plots on the experimental field, and the method of fertilizing each plot, are illustrated by the diagram below. The field is divided into five plots, each one-eighth acre in size, with strips 3.3 feet wide between them. In planting the field these strips between the plots, as well as similar strips at the sides and ends of the field, are planted the same as the plots, but no manure nor fertilizer of any kind is used on them, and the crop which grows on them is removed before that on the plots. In carrying out these experiments the same crop will be grown on the whole field in the same year, and the crops will vary from year to year in the following order of rotation: Corn, potatoes, oats and peas for fodder, and soy beans.

Diagram illustrating arrangement and method of fertilizing plots in experiment on soil improvement.

The narrow strips at the sides and ends of the plots are without fertilizer.

PLOT K. "Complete" fertilizer, 1200 lbs. per acre.

PLOT L. Stable manure, 12 tons per acre.

PLOT M. No fertilizer, but clover or other legume for green manuring.

PLOT N. Mineral fertilizers, 700 lbs. per acre, and rye for green manuring.

PLOT P. Mineral fertilizers, 700 lbs. per acre, and clover for green manuring.

On plot K will be used a "complete" fertilizer, which will be composed of several of the various ingredients commonly used in different chemical fertilizers, in quantities sufficient to supply liberal amounts of phosphoric acid, potash, and nitrogen per acre. On plot L will be used good mixed stable manure at the rate of twelve tons per acre. On plot M no fertilizer will be used, but clover or some other legume, sown either in the spring with the crop, as with oats, or in the fall as a catch crop after the removal of the regular crop, will be allowed to

grow until the following spring and then turned under for green manuring. On plot N 700 pounds of mineral fertilizers, consisting of 200 pounds muriate of potash and 500 pounds South Carolina acid phosphate, will be used with the regular crop grown in the experiment, and rye will be sown for a catch crop in the fall and plowed under the following spring. On plot P the same kinds and amounts of mineral fertilizers will be used as on plot N, but clover or some other legume will be sown as a catch crop and plowed under in the spring. The same plots are to be fertilized in the same manner as here described year after year. An effort will be made each year to have the money value of the stable manure equal to that of the complete fertilizer. The values of both the complete fertilizer and the mineral fertilizers used will be determined according to the system of valuation adopted annually by the New England Experiment Stations; the value of the stable manure for the present will be considered as $3 per cord of 4,500 pounds.

In 1899 the ingredients of the complete fertilizer on plot K, and the rates per acre at which they were combined, were as follows: Nitrate of soda, 200 pounds; sulphate of ammonia, 100 pounds; tankage, 200 pounds; South Carolina acid phosphate, 500 pounds, making a total of 1,200 pounds of the mixture per acre. The stable manure on plot L was a mixture of horse and cattle manure, weighing 4,500 pounds to the cord, and was used at the rate of 12 tons or 5⅓ cords per acre. There was no fertilizer applied on plot M, and as no clover had been planted the preceding year there was none to plow under for green manuring in 1899. The next two plots, N and P, were fertilized with the minerals as indicated above, but, as in the case of plot M, no crops were ready to plow under until after the removal of the crop grown for experiment in 1899. On July 20, after the corn was well grown, alsike clover was sown on plots M and P at the rate of twenty-four pounds of seed per acre; rye was sown on plot N after the corn was harvested.

The yields from the different plots for the preliminary experiment of 1899 are given in Table 51. Inasmuch as the conditions of this experiment were such that no crops for green manuring could be grown so as to be of use as fertilizer for the first year's crop, the results are not discussed in this report.

TABLE 51.

Yields of corn and stover from the different plots in the preliminary experiment on soil improvement in 1899.

Plot No.	Fertilizers.			Yield per Plot. ⅛ Acre.			Yield per Acre.		
	Kind.	Weights per acre.	Cost per acre.	Shelled corn. Good.	Shelled corn. Poor.	Stover.	Shelled corn. Good.	Shelled corn. Poor.	Stover.
		Lbs.	$	Lbs.	Lbs.	Lbs.	Bu.	Bu.	Lbs.
K	Complete fertilizer, - -	1200	16.94	495.0	24.6	1020	70.7	3.5	8160
L	Stable manure, - - -	24000	16.00	415.8	35.6	855	59.0	5.1	6840
M	No fertilizer, - - -	—	—	360.4	24.4	872	51.5	3.5	6976
N	Mineral fertilizer, - -	700	7.18	403.3	15.9	788	57.6	2.2	6304
P	Mineral fertilizer, - -	700	7.18	375.4	22.8	705	53.6	3.3	5640

ANALYSES OF FODDERS AND FEEDING STUFFS.

BY F. G. BENEDICT.

During the past year analyses have been made of over 200 food materials used in connection with metabolism and digestion experiments with men, and of about 120 samples of crops grown in field experiments with fertilizers. The methods of analysis were those recommended by the Association of Official Agricultural Chemists, with such minor modifications as have been found desirable.*

The descriptions and results of analyses of food materials used in the experiments with man will be published with other details of the investigations. The descriptions and results of the analyses of the samples of field crops are given on pages 211–218 of the present Report. The data of Table 52 show only the percentages of water, dry matter, nitrogen, and protein (N. × 6.25) in the fresh substance, and of nitrogen and protein (N. × 6.25) in the water-free material, as these suffice to indicate the proportions of nitrogen in the crop and also the effect of the nitrogenous fertilizers upon the proportions of protein in the plants. In previous Reports the complete analyses of both fresh and dry substances have been given, but the work of the Station has increased to such extent as to make it necessary to reduce the details to the minimum consistent with the purpose of the inquiry. It would have been interesting to determine the proportions of proteid and non-proteid nitrogen had the resources of the Station and the accuracy of the methods now in use been such as to warrant it. Tests for the presence of nitric acid were made in a considerable number of samples, especially those from the plots in which the largest quantities of nitrogen were applied in the fertilizers. In a few cases there were indications of minute quantities of nitric acid in the samples tested, but in most not even traces were detected.

* See Report of this Station for 1891.

For the sake of comparison of the results of these experiments with those given in former Reports, the protein in Table 52 is calculated by the usual method, as nitrogen multiplied by the factor 6.25, according to the assumption that protein contains sixteen per cent. of nitrogen. It has been repeatedly pointed out, however, that this factor is only approximately correct. This matter is discussed in some detail on page 76 of the present Report.

Two sets of averages are given in Table 52 beyond. The first are the averages of the analyses that are published for the first time in the present Report; the second are the averages of all analyses of similar materials made in this laboratory up to the present time.

DESCRIPTION OF SAMPLES.

All the analyses reported in the following table, excepting those of soy bean fodder (No. 6089), and silage corn (No. 6090), are those of crops grown in the plot experiments conducted by the Station for the purpose of studying the effects of different kinds and amounts of nitrogenous fertilizers upon the yield and composition of different crops. For convenience in describing the samples and the growth of the crop from which they were taken, it may be stated here* that all plots on the experimental field having the same number have the same kinds and amounts of fertilizers per acre. In the following descriptions of samples, therefore, the number of the plot will serve to indicate the fertilizer used in growing the crop, as shown by the scheme given here:

Plot No.	Kinds of Fertilizer Applied and Amounts per Acre.			
	Dissolved bone-black.	Muriate of potash.	Nitrate of soda.	Sulphate of ammonia.
	Lbs.	Lbs.	Lbs.	Lbs.
0, 00	—	—	—	—
6*a*, 6*b*	320	160	—	—
7	320	160	160	—
8	320	160	320	—
9	320	160	480	—
10	320	160	—	160
11	320	160	—	320
12	320	160	—	480

* For more complete description of the experiments see previous Reports of the Station, and also pages 168-204 of the present Report.

GRASSES AND GREEN FODDERS.

The following grasses were grown on plots in the Station grass garden during the year 1899. A large sample was taken from each of the plots, composed of small quantities of grass taken from several different parts of the plot, except from a strip next to other plots and next to paths. Care was taken to exclude from the sample all clover and all other grasses than the one to be analyzed. Each large sample was cut at once into pieces about one inch long, which were then thoroughly mixed. From this mass a smaller sample was taken, and, after being weighed, was dried in a steam drier especially constructed for such purpose.

Nos. 6071–6074. Brome grass (Bromus inermis).—Samples taken June 27, 1899, when in late bloom, some seed forming.

No. 6071 was from plot 0. Growth very light, thin, spindled, irregular, pale in color. Hardly sufficient grass on plot for a good sample. Some weeds and odd grasses on plot.

No. 6072 was from plot 6. Growth light, thin, slender, pale in color, slightly heavier than on plot 0. Some clover and odd grasses on plot.

No. 6073 was from plot 7. Growth medium heavy, good color, and fair proportion of bottom growth. (Not so good growth as that of fescue and orchard grass on corresponding plots.) Some weeds and odd grasses on plot.

No. 6074 was from plot 9. Growth heavy, dense, rich green in color, with fair proportion of bottom grass. (Not so heavy growth as that of fescue or orchard grass on corresponding plots.)

Nos. 6067–6070. Meadow fescue (Festuca elatior).—Samples were taken July 3, 1899, when the grass was in early seed stage.

No. 6067 was grown on plot 0. The growth was very thin, slender, pale in color, with practically no bottom growth. Only a little grass was left after the sample was cut. Some weeds and odd grasses grew on the plot.

No. 6068 was from plot 6. The growth was thin, light, pale in color, with practically no bottom growth. A little heavier than that on plot 0. Some weeds, clover, and odd grasses on the plot.

No. 6069 was from plot 7. The growth was much heavier than that on plot 6, of fair color, medium bottom growth. Some weeds and odd grasses on the plot.

No. 6070 was from plot 9. The growth was heavy, dense, of dark green color, with very heavy bottom growth. Some odd grasses on plot.

Nos. 6063–6066. Orchard grass (Dactylis glomerata).—Samples taken June 12, 1899, when a little past full bloom.

No. 6063 was from plot 0. The growth was thin and spindled, pale in color, with little bottom growth. There was a considerable mixture of weeds and other grasses and some clover on the plot.

No. 6064 was from plot 6. Growth thin and spindled, pale in color, little bottom growth. But little heavier growth than on plot 0. Considerable mixture of clover, with some weeds and other grasses.

No. 6065 was grown on plot 7. Growth fair, dark green color, much heavier than on plot 6, with considerable bottom growth. Some weeds and odd grasses on plot.

No. 6066 was grown on plot 9. Growth dense and heavy, about twice as heavy as on plot 7; dark green color, thick bottom growth. Some odd grasses on the plot.

Nos. 6075–6078. Timothy (Phleum pratense). Samples taken July 6, 1899, when the grass was in early seed stage.

No. 6075 was from plot o. Growth very thin, light, and irregular; pale in color. Practically no bottom growth. Large proportion of weeds and odd grasses on plot.

No. 6076 was from plot 6. Growth very thin, light, and irregular; pale in color, with practically no bottom growth. Somewhat heavier than that on plot o. Considerable clover and odd grasses.

No. 6077 was from plot 7. Growth medium heavy, fair color, little bottom growth. Some weeds and odd grasses on plot.

No. 6078 was from plot 9. Growth heavy, dense; rich green color; about twice as heavy as that on plot 7. Fair proportion of bottom growth. Some weeds and odd grasses on plot.

Of the following green fodders, Nos. 6079-6088 were grown as part of the special nitrogen experiments already mentioned, while Nos. 6089–6090 were grown especially for fodder. In each case a large sample, weighing from forty to fifty pounds, was taken by removing small quantities from different parts of the crop as it was being cut up in a silage cutter. Each large sample was thoroughly mixed, then a sub-sample was taken, weighed, and dried in the steam drier.

Nos. 6079–6088. Cow pea fodder.—Samples taken September 27, 1899.

Nos. 6079 and 6080 were from plots o and oo respectively. The crop on these plots was very light; growth small and slender; the plants were drying up when harvested.

Nos. 6081 and 6082 were from plots 6*a* and 6*b* respectively. Growth quite heavy, succulent, with few seed pods; good color, and much the same growth as on nitrogen plots.

No. 6083 was from plot 7. Growth quite heavy, succulent, few seed pods.

No. 6084 was from plot 8. Growth fair, succulent, few seed pods. Crop not so heavy as on plot 7.

No. 6085 was from plot 9. Fair growth, succulent; not so heavy as on plot 7. Few seed pods.

No. 6086 was from plot 10. Growth quite heavy, succulent, few seed pods. Crop better than on plots 11 and 12.

No. 6087 was from plot 11. Growth medium heavy, succulent, few immature seed pods. Crop not so heavy as that on plot 9.

No. 6088 was from plot 12. Medium heavy growth, succulent, few immature seed pods. Crop not so heavy as on plot 9.

No. 6089. Soy bean fodder.*—Grown for silage, with mineral fertilizers only. Sample taken on September 25, 1899, from about a ton of the fodder which was being cut in silage cutter. There was a medium growth of fodder, which was quite well seeded when cut, but was still green and quite succulent.

No. 6090. Ensilage corn (Ohio white dent).* Sample taken on September 25, 1899, from eleven rows as weighed for test of yield. The corn (grain) was mostly in the " dough " stage, some of it just beginning to glaze. The stalks were green and succulent. About fifty pounds were taken for a large sample as the crop was being run through a silage cutter; this was mixed and sub-sampled.

* The complete analyses of these two samples were made. The composition of each, in the water-free substance and calculated to water content at time of taking sample, is shown in the table on the following page.

Complete analyses of samples Nos. 6089 and 6090.

Lab. No.	FEEDING STUFFS.	Water.	Protein.	Fat.	Nit.-free ext.	Fiber.	Ash.	Fuel value per Lb.
	In Water-free Substance.	%	%	%	%	%	%	Cal.
6089	Soy bean fodder,	—	17.56	8.57	40.05	28.75	8.07	1965
6090	Ensilage corn,	—	7.84	4.95	61.00	21.24	4.97	1885
	In Fresh Substance.							
6089	Soy bean fodder,	74.86	4.42	2.15	10.07	6.47	2.03	480
6090	Ensilage corn,	74.00	2.04	1.29	15.86	5.52	1.29	490

CURED FODDERS.

Of the following cured fodders Nos. 6022–6031 and Nos. 6033–6042 were from the special nitrogen experiments of 1898, and Nos. 6091–6110 were from the same experiments of 1899. The samples of stover were taken just after the corn was husked and the stover was weighed. In 1898 a large sample of stover was taken from each plot by gathering small quantities from different parts of the total crop on the plot. These were cut into pieces one to two inches long, which were then thoroughly mixed, and from different parts of the whole mass a smaller sub-sample was taken, which was weighed and dried in the steam drier. In 1899 the entire crop of stover on each plot was cut into small pieces and mixed, and from this a sub-sample was taken.

Nos. 6022–6031, 6033–6042. Stover of white flint corn.—Grown in 1898. Nos. 6022–6031 were from plots on the north side of the field, on which lime was applied in addition to the regular fertilizers. Nos. 6033–6042 were from plots on the south side of the field on which the fertilizers were applied without the lime. The dates of taking the samples were as follows: Nos. 6034, 6035, 6036, 6040 on November 11; Nos. 6033, 6037, 6041 on November 14; Nos. 6022, 6030, 6031, 6038, 6039 on November 16; and Nos. 6023 to 6029, inclusive, on November 17.

Nos. 6022 and 6023 were from plots 00 and 0. The growth on plot 0 was small, spindled, pale in color, with few ears; mostly "poor" or unmerchantable corn. On plot 00 the stalks were small and slender, ears small, corn mostly poor or unmerchantable.

Nos. 6024 and 6025 were from plots 6*a* and 6*b*. Stalks were small and slender, pale in color; small proportion of merchantable ears.

No. 6026 was from plot 7. Growth better than on plot 6; stalks medium in size, color fair, ears and total crop rather light.

No. 6027 was from plot 8. Growth and color of stalks fair, with fair proportion of ears; better crop than on plot 7.

No. 6028 was from plot 9. Growth of stalks quite heavy and of good color. Fair growth of ears.

No. 6029 was from plot 10. Fair sized stalks of good color; fair proportion of good or merchantable ears. Growth was considerably better than that on plot 7, and much better than that on corresponding plot on south end of field.

No. 6030 was from plot 11. Growth on the whole much like that on plot 10; much better than that on corresponding plot on south end of field.

No. 6031 was from plot 12. Stalks rather small and slightly pale in color. Growth not so heavy as on plots 10 and 11, but much better than that on corresponding plot on south end of field.

Nos. 6033 and 6034 were from plots 0 and 00 respectively. The growth on plot 0 was small and spindling, pale in color, and with few ears. The growth on plot 00 was somewhat better, but stalks and ears were small. The ears in both crops were mostly "poor," or unmerchantable. There were many immature or partially developed kernels on the ears.

Nos. 6035 and 6036 were from plots 6*a* and 6*b* respectively. The growth on plot 6*a* was small, spindled, pale in color, but better than on plot 0, with not many merchantable ears. The growth on plot 6*b* was similar, with a little better color, and ears slightly better. The proportion of merchantable ears was small.

No. 6037 was from plot 7. The growth on this plot was rather small, of fair color, with small proportion of ears. Many hills were missing.

No. 6038 was from plot 8. The growth on this plot was better than that on plot 7, of fair color, and fair proportion of ears. Many hills missing.

No. 6039 was from plot 9. The stover moulded a little when curing. The growth on this plot was heavier than that on plot 8; the color was good, ears fair.

No. 6040 was from plot 10. The growth on this plot was heavier than that on plot 7; good color, fair growth of ears.

No. 6041 was from plot 11. The growth was much the same as on plot 8. Color good and fair growth of ears.

No. 6042 was from plot 12. The growth was much the same as that on plot 9; good color, but paler than that on plot 11; fairly heavy, and good growth of ears. Some hills missing.

Nos. 6091–6110. Stover of white flint corn.—Grown in 1899. Nos. 6091 to 6100 were from plots on the north side of the field, on which lime was applied in addition to the regular fertilizers. These were sampled on October 18, 1899. Nos. 6101 to 6110 were from plots on the south side of the field, without the addition of lime. These were sampled October 20, 1899.

Nos. 6091 and 6092 were from plots 0 and 00 respectively. The stalks were very slender, the ears few and small.

Nos. 6093 and 6094 were from plots 6*a* and 6*b* respectively. The stalks were medium heavy, but pale in color; the proportion of ears was small.

No. 6095 was from plot 7. Fair growth of stalks and ears; stalks of good color.

No. 6096 was from plot 8. Good growth of stalks and ears; stalks of good color.

No. 6097 was from plot 9. Growth like that on plot 8.

No. 6098 was from plot 10. Growth much the same as on plot 7.

No. 6099 was from plot 11. Growth much the same as on plot 8.

No. 6100 was from plot 12. Growth better than that on plot 9.

Nos. 6101 and 6102 were from plots 0 and 00 respectively. Stalks small and slender; ears very few and small.

Nos. 6103 and 6104 were from plots 6*a* and 6*b* respectively. Fair growth of stalks, pale in color. Small proportion of ears.

No. 6105 was from plot 7. Fair growth of stalks and ears. Stover rather slender, fair in color.

No. 6106 was from plot 8. Fair growth of stalks and ears, dark green stover; crop nearly as good as on plot 9.

No. 6107 was from plot 9. Fair growth of stalks and ears; stover dark green.

No. 6108 was from plot 10. Light growth of stalks and ears, about the same as on plot 7.

No. 6109 was from plot 11. Growth light; not equal to that on plot 8, but better than that on plot 12.

No. 6110 was from plot 12. Growth light, not so good as that on plot 9.

SEEDS.

Nos. 6111–6120. Soy bean seed.—Grown in 1899. Samples of about a quart each were taken December 28, 1899, after the weighing of the total crop of seeds from each plot was made.

Nos. 6111 and 6112 were from plots 0 and 00 respectively. Growth light, plants very small, seed fairly good.

Nos. 6113 and 6114 were from plots 6*a* and 6*b* respectively. On both plots the seeds were well matured. The growth on 6*a* was medium heavy; that on 6*b* was nearly equal to that on the best nitrogen plots.

No. 6115 was from plot 7. Seed well matured, medium growth; much the same as on plot 10.

Nos. 6015 and 6016 were from plots 8 and 9 respectively. The growth on these two plots was about alike, quite heavy, with seed well matured.

No. 6118 was from plot 10. Growth much the same as on plot 7.

No. 6119 was from plot 11. Growth not quite so heavy as that on plot 8.

No. 6120 was from plot 12. Growth not so heavy as on plot 9.

Nos. 6043–6062. White flint corn (Grain).—Grown in 1898. Nos. 6043 to 6052 were from plots on the south side of the field, Nos. 6053 to 6062 from plots on the north side. The entire growth of corn (ears) from each plot was dried in the Station barn from the time of husking until February 18, 1899; it was then shelled and dried farther until March 17, the date of sampling. At this date the corn was weighed, and from each crop a sample of two quarts was taken, from which about one quart of "good" kernels was selected for a final sample, which was then sealed in a tight jar. For description of the growth on the different plots see description of the corresponding samples of stover, Nos. 6022–6031, 6033–6042.

Nos. 6140–6159. White flint corn (Grain).—Grown in 1899, sampled January 15, 1900. A sample of about three pints was taken from the total amount of "good" corn from each plot at the time of weighing the yields from the plot. The chaff and immature corn was picked out and discarded, and the sample sealed in a quart jar. Nos. 6140 to 6149 were from plots on the south side of the field; Nos. 6150–6159 from plots on the north side. For description of the growth on the different plots see description of the corresponding samples of stover, Nos. 6091–6110.

TABLE 52.

Composition of samples of field crops grown with different fertilizers.

[Averages of analyses here given together with those of former years.]

Lab. No.	Material.	In Water-free Substance.		In Fresh Substance.			
		Nitrogen.	Protein. N.×6.25.	Water.	Dry matter.	Nitrogen.	Protein. N.×6.25.
		%	%	%	%	%	%
6071	Bromus inermis, - -	1.09	6.81	62.3	37.7	.4	2.6
6072	Bromus inermis, - -	1.17	7.31	64.8	35.2	.4	2.6
6073	Bromus inermis, - -	1.24	7.75	66.8	33.2	.4	2.6
6074	Bromus inermis, - -	1.23	7.69	70.4	29.6	.4	2.3
	Average (4), - - -	**1.18**	**7.39**	**66.1**	**33.9**	**.4**	**2.5**
	Average all analyses (12),	**1.41**	**8.79**	**65.8**	**34.2**	**.5**	**3.1**
6067	Meadow fescue, - -	1.01	6.31	65.6	34.4	.4	2.2
6068	Meadow fescue, - -	.99	6.19	68.5	31.5	.3	1.9
6069	Meadow fescue, - -	1.24	7.75	69.9	30.1	.4	2.3
6070	Meadow fescue, - -	1.58	9.88	73.6	26.4	.4	2.6
	Average (4), - - -	**1.21**	**7.53**	**69.4**	**30.6**	**.4**	**2.3**
	Average all analyses (26),	**1.36**	**8.50**	**69.8**	**30.2**	**.4**	**2.5**
6063	Orchard grass, - - -	1.24	7.75	70.8	29.2	.4	2.3
6064	Orchard grass, - - -	1.22	7.63	71.9	28.1	.3	2.1
6065	Orchard grass, - - -	1.21	7.56	75.3	24.7	.3	1.9
6066	Orchard grass, - - -	1.81	11.31	76.5	23.5	.4	2.6
	Average (4), - - -	**1.37**	**8.56**	**73.6**	**26.4**	**.4**	**2.2**
	Average all analyses (28),	**1.48**	**9.23**	**69.5**	**30.5**	**.4**	**2.8**
6075	Timothy, - - - -	1.09	6.81	57.5	42.5	.5	2.9
6076	Timothy, - - - -	1.04	6.50	59.5	40.5	.4	2.6
6077	Timothy, - - - -	.98	6.12	62.0	38.0	.4	2.3
6078	Timothy, - - - -	1.14	7.12	63.1	36.9	.4	2.6
	Average (4), - - -	**1.06**	**6.64**	**60.5**	**39.5**	**.4**	**2.6**
	Average all analyses (28),	**1.23**	**7.66**	**65.7**	**34.3**	**.4**	**2.6**
6079	Cow pea fodder, - -	3.33	20.81	83.7	16.3	.5	3.4
6080	Cow pea fodder, - -	3.73	23.31	83.8	16.2	.6	3.8
6081	Cow pea fodder, - -	3.38	21.12	85.0	15.0	.5	3.2
6082	Cow pea fodder, - -	3.23	20.19	85.3	14.7	.5	2.9
6083	Cow pea fodder, - -	3.37	21.06	85.2	14.8	.5	3.1
6084	Cow pea fodder, - -	3.15	19.69	84.8	15.2	.5	3.0
6085	Cow pea fodder, - -	3.67	22.94	85.2	14.8	.5	3.4
6086	Cow pea fodder, - -	3.21	20.07	84.3	15.7	.5	3.1
6087	Cow pea fodder, - -	3.34	20.88	84.7	15.3	.5	3.2
6088	Cow pea fodder, - -	3.67	22.94	85.8	14.2	.5	3.3
	Average (10), - -	**3.41**	**21.30**	**84.8**	**15.2**	**.5**	**3.2**
	Average all analyses (77),	**2.97**	**18.54**	**83.1**	**16.9**	**.5**	**3.1**
6089	Soy bean fodder,* - -	2.81	17.56	74.9	25.1	.7	4.4
	Average all analyses (17),	**2.51**	**15.67**	**76.2**	**23.8**	**.6**	**3.7**
6022	Corn stover, - - -	1.33	8.31	30.1	69.9	.9	5.8
6023	Corn stover, - - -	.93	5.81	23.6	76.4	.7	4.4

* For complete analysis of this sample see p. 213.

TABLE 52.—*(Continued.)*

Lab. No.	MATERIAL.	In Water-free Substance. Nitrogen.	In Water-free Substance. Protein. N.×6.25.	In Fresh Substance. Water.	In Fresh Substance. Dry matter.	In Fresh Substance. Nitrogen.	In Fresh Substance. Protein. N.×6.25.
		%	%	%	%	%	%
6024	Corn stover,	.86	5.37	29.1	70.9	.6	3.8
6025	Corn stover,	.78	4.88	28.8	71.2	.6	3.5
6026	Corn stover,	.83	5.19	27.1	72.9	.6	3.8
6027	Corn stover,	.89	5.56	26.4	73.6	.7	4.1
6028	Corn stover,	1.06	6.62	36.4	63.6	.7	4.2
6029	Corn stover,	.75	4.69	26.7	73.3	.6	3.4
6030	Corn stover,	.81	5.06	33.1	66.9	.5	3.4
6031	Corn stover,	.89	5.56	39.1	60.9	.5	3.4
6033	Corn stover,	1.25	7.81	31.4	68.6	.9	5.4
6034	Corn stover,	1.45	9.06	38.0	62.0	.9	5.6
6035	Corn stover,	1.09	6.81	37.2	62.8	.7	4.3
6036	Corn stover,	1.04	6.50	31.8	68.2	.7	4.4
6037	Corn stover,	1.00	6.25	35.7	64.3	.6	4.0
6038	Corn stover,	.91	5.69	29.7	70.3	.6	4.0
6039	Corn stover,	1.00	6.25	42.0	58.0	.6	3.6
6040	Corn stover,	.93	5.81	33.6	66.4	.6	3.9
6041	Corn stover,	.97	6.06	42.4	57.6	.6	3.5
6042	Corn stover,	1.09	6.81	38.4	61.6	.7	4.2
6091	Corn stover,	1.44	9.00	31.7	68.3	1.0	6.1
6092	Corn stover,	1.86	11.63	31.9	68.1	1.3	7.9
6093	Corn stover,	1.06	6.62	42.1	57.9	.6	3.8
6094	Corn stover,	.93	5.81	41.3	58.7	.5	3.2
6095	Corn stover,	.99	6.19	42.8	57.2	.6	3.6
6096	Corn stover,	1.20	7.50	37.3	62.7	.8	4.7
6097	Corn stover,	1.15	7.19	43.5	56.5	.7	4.1
6098	Corn stover,	1.25	7.81	39.3	60.7	.8	4.8
6099	Corn stover,	1.27	7.94	45.0	55.0	.7	4.4
6100	Corn stover,	1.31	8.19	49.6	50.4	.7	4.1
6101	Corn stover,	1.37	8.56	27.3	72.7	1.0	6.3
6102	Corn stover,	1.66	10.37	28.1	71.9	1.2	7.5
6103	Corn stover,	1.20	7.50	35.7	64.3	.8	4.8
6104	Corn stover,	.97	6.06	32.4	67.6	.7	4.1
6105	Corn stover,	1.50	8.12	38.8	61.2	.8	4.9
6106	Corn stover,	1.39	8.69	30.1	69.9	1.0	6.1
6107	Corn stover,	1.81	11.31	38.8	61.2	1.1	6.9
6108	Corn stover,	1.18	7.38	34.8	65.2	.8	4.8
6109	Corn stover,	2.03	12.69	34.2	65.8	1.3	8.4
6110	Corn stover,	2.36	14.75	36.4	63.6	1.5	9.4
	Average (40),	**1.19**	**7.44**	**35.0**	**65.0**	**.8**	**4.8**
	Average all analyses (220),	**1.05**	**6.58**	**39.8**	**60.2**	**.6**	**3.9**
6090	Ensilage corn,*	1.26	7.84	74.0	26.0	.3	2.0
	Average all analyses (2),	**1.35**	**8.42**	**73.1**	**26.9**	**.4**	**2.3**
6111	Soy beans,	6.80	42.50	9.2	90.8	6.2	38.6
6112	Soy beans,	7.53	47.06	9.4	90.6	6.8	42.6
6113	Soy beans,	6.65	41.57	7.8	92.2	6.1	38.3
6114	Soy beans,	6.23	38.94	7.1	92.9	5.8	36.2
6115	Soy beans,	6.49	40.57	8.2	91.8	6.0	37.3
6116	Soy beans,	6.41	40.06	7.4	92.6	5.9	40.1

* For complete analysis of this sample see p. 213.

TABLE 52.—*(Continued.)*

Lab. No.	MATERIAL.	In Water-free Substance.		In Fresh Substance.			
		Nitrogen.	Protein. N.×6.25.	Water.	Dry matter.	Nitrogen.	Protein. N.×6.25.
		%	%	%	%	%	%
6117	Soy beans, - - -	6.61	41.31	8.3	91.7	6.1	37.9
6118	Soy beans, - - -	6.55	40.94	8.8	91.2	6.0	37.4
6119	Soy beans, - - -	6.54	40.88	8.4	91.6	6.0	37.4
6120	Soy beans, - - -	6.92	43.25	8.3	91.7	6.3	39.6
	Average (10), - -	**6.67**	**41.71**	**8.3**	**91.7**	**6.1**	**38.5**
	Average all analyses (45),	**6.18**	**38.64**	**8.3**	**91.7**	**5.9**	**37.1**
6043	White flint corn, - -	1.71	10.69	11.8	88.2	1.5	9.4
6044	White flint corn, - -	1.74	10.88	15.1	84.9	1.5	9.3
6045	White flint corn, - -	1.56	9.75	13.4	86.6	1.4	8.4
6046	White flint corn, - -	1.57	9.81	14.7	85.3	1.3	8.4
6047	White flint corn, - -	1.68	10.50	14.4	85.6	1.4	9.0
6048	White flint corn, - -	1.66	10.38	13.9	86.1	1.4	8.9
6049	White flint corn, - -	1.83	11.44	15.1	84.9	1.6	9.7
6050	White flint corn, - -	1.69	10.56	15.6	84.4	1.4	8.9
6051	White flint corn, - -	1.69	10.56	16.4	83.6	1.4	8.8
6052	White flint corn, - -	1.73	10.81	15.5	84.5	1.5	9.1
6053	White flint corn, - -	1.57	9.81	15.7	84.3	1.3	8.3
6054	White flint corn, - -	1.70	10.62	16.8	83.2	1.4	8.8
6055	White flint corn, - -	1.55	9.69	15.0	85.0	1.3	8.3
6056	White flint corn, - -	1.55	9.69	14.5	85.5	1.3	8.3
6057	White flint corn, - -	1.66	10.37	18.5	81.5	1.4	8.4
6058	White flint corn, - -	1.61	10.07	15.4	84.6	1.4	8.5
6059	White flint corn, - -	1.70	10.62	16.9	83.1	1.4	8.8
6060	White flint corn, - -	1.62	10.12	16.6	83.4	1.4	8.4
6061	White flint corn, - -	1.60	10.00	14.2	85.8	1.4	8.6
6062	White flint corn, - -	1.67	10.44	14.9	85.1	1.4	8.9
6140	White flint corn, - -	1.79	11.19	11.7	88.3	1.6	9.9
6141	White flint corn, - -	1.79	11.19	12.7	87.3	1.6	9.8
6142	White flint corn, - -	1.46	9.13	12.9	87.1	1.3	7.9
6143	White flint corn, - -	1.53	9.56	12.8	87.2	1.3	8.3
6144	White flint corn, - -	1.60	10.00	11.2	88.8	1.4	8.9
6145	White flint corn, - -	1.60	10.00	11.3	88.7	1.4	8.9
6146	White flint corn, - -	1.78	11.12	13.6	86.4	1.5	9.6
6147	White flint corn, - -	1.61	10.06	11.3	88.7	1.4	8.9
6148	White flint corn, - -	1.70	10.63	11.9	88.1	1.5	9.4
6149	White flint corn, - -	1.73	10.81	13.8	86.2	1.5	9.3
6150	White flint corn, - -	1.63	10.19	10.3	89.7	1.5	9.1
6151	White flint corn, - -	1.79	11.19	10.4	89.6	1.6	10.0
6152	White flint corn, - -	1.65	10.31	12.6	87.4	1.4	9.0
6153	White flint corn, - -	1.58	9.87	11.5	88.5	1.4	8.8
6154	White flint corn, - -	1.65	10.31	11.1	88.9	1.5	9.2
6155	White flint corn, - -	1.75	10.94	13.5	86.5	1.5	9.4
6156	White flint corn, - -	1.82	11.37	12.7	87.3	1.6	9.9
6157	White flint corn, - -	1.85	11.56	14.6	85.4	1.6	9.9
6158	White flint corn, - -	1.86	11.63	14.5	85.5	1.6	9.9
6159	White flint corn, - -	1.84	11.50	13.8	86.2	1.6	9.9
	Average (40), - -	**1.68**	**10.48**	**13.8**	**86.2**	**1.4**	**9.0**
	Average all analyses (213),	**1.83**	**11.44**	**18.0**	**82.0**	**1.4**	**9.0**

METEOROLOGICAL OBSERVATIONS.

REPORTED BY C. S. PHELPS.

The meteorological observations made under the directions of the Station during 1899 were similar to those of previous years. The Station equipment at Storrs consists of the ordinary instruments for observing temperatures, pressure of the air, humidity, rainfall, snowfall, and velocity of the wind, similar to those in use by the Weather Service of the United States Department of Agriculture. In addition to the records made at Storrs, the rainfall for the summer season (May 1 to October 31) has been recorded by ten farmers in different parts of the State in coöperation with the Station.

The total precipitation for the year (38.3 inches) was 6.8 inches below the average at Storrs for the past eleven years, and about 10 inches below the general average for Connecticut, as computed from the records of the New England Meteorological Society's observers, who have made observations covering periods of from five to thirty years. The rainfall was especially deficient for April and May, and for June up to the middle of the month. The deficiency in the rainfall during this period greatly reduced the yield of hay so that the crop was one of the lightest for many years. The rainfall for the balance of the growing season was ample and most other crops gave normal yields.

The average temperature for February was unusually low, while for March and April it was about normal. The spring opened favorably for farm work and most crops were planted earlier than usual. The last killing frost in the spring occurred May 4. The temperature for June was somewhat above the normal, but for the balance of the summer it was about the average. The growing season was shorter than usual, light frosts occurring September 7 and 14, and quite severe frosts September 15 and 16. The growing season from the time of the last severe frost in the spring to that of the first in the fall was only 134 days, while the average growing season at Storrs

for the past twelve years has been 146 days. An unusually severe freeze occurred October 2, and another October 3, small pools of water being frozen over one-third of an inch in thickness and potatoes which were not harvested were considerably frozen.

With the exception of the severe freeze just referred to the fall months were mild and very favorable for the harvesting of crops. The first snow occurred November 14, but remained on the ground only a few days, and the fields were bare most of the time until the close of the year.

Through the kindness of the New England Meteorological Society we are able to publish the rainfall records from ten of their stations in Connecticut. Table 53 gives the rainfall as recorded for the six months ending October 31 for twenty-one localities in the State, and Table 54 gives the summary of observations made by the Station at Storrs.

TABLE 53.

Rainfall during six months ending October 31, 1899.

Locality.	Observer.	Inches per Month.						
		May.	June.	July.	August.	September.	October.	Total.
Canton,	G. J. Case,	2.09	6.44	6.83	3.00	4.83	2.50	25.69
Clark's Falls,	E. D. Chapman,	2.30	2.74	5.00	2.96	2.93	1.87	17.80
Colchester,	S. P. Willard,	2.11	2.82	5.38	4.21	3.47	1.21	19.20
Cream Hill,	C. L. Gold,	1.75	3.39	6.70	1.11	4.21	1.67	18.83
Falls Village,	M. H. Dean,	2.68	3.99	7.09	.88	4.82	1.63	21.09
Gilead,	A. C. Gilbert,	1.71	3.49	4.30	3.37	3.53	2.00	18.40
Hartford,	Prof. S. Hart,	1.71	3.07	6.23	1.92	3.60	2.98	19.51
Lebanon,	E. A. Hoxie,	3.10	3.58	5.43	4.58	6.29	2.25	25.23
Madison,	J. D. Kelsey,	2.69	2.58	5.10	.55	3.24	1.51	15.67
New Haven,	Weather Bureau,	2.52	2.59	4.17	.65	3.33	1.78	15.04
Newington,	J. S. Kirkham,	1.41	1.88	6.99	1.35	3.27	2.43	17.33
New London,	Weather Bureau,	2.52	2.60	5.29	2.59	4.32	1.87	19.19
North Franklin,	C. H. Lathrop,	1.84	3.57	4.82	4.12	5.25	2.30	21.90
Norwalk,	G. S. Comstock,	2.05	3.06	5.91	.37	4.80	1.42	17.61
Southington,	Lumen Andrews,	1.75	2.23	5.62	.45	4.13	2.35	16.53
South Manchester,	K. B. Loomis,	2.22	2.21	4.73	1.36	3.02	2.66	16.20
Storrs,	Experiment Station,	1.27	3.72	5.55	3.27	3.31	1.54	18.66
Voluntown,	Rev. C. Dewhurst,	1.52	2.59	4.58	2.22	8.41	1.43	20.75
Waterbury,	N. J. Welton,	2.07	2.32	6.02	1.03	5.30	2.42	19.16
West Simsbury,	S. T. Stockwell,	2.04	6.71	6.60	3.79	4.29	1.87	25.30
Winchester,	W. L. Wetmore,	1.66	2.62	6.19	1.44	3.37	1.67	16.95
	Average,	**2.05**	**3.25**	**5.64**	**2.15**	**4.27**	**1.97**	**19.34**

TABLE 54.

Meteorological Summary for 1899.

OBSERVATIONS MADE AT STORRS BY THE STATION.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.	Total.
Highest barometer, - -	30.90	30.54	30.54	30.36	30.33	30.26	30.26	30.35	30.49	30.49	30.49	30.79	30.49	—
Lowest barometer, - -	29.39	29.18	29.39	29.53	29.73	29.75	29.72	29.80	29.65	29.77	29.46	29.28	29.55	—
Mean barometer, - - -	30.17	30.01	30.09	30.07	30.05	30.03	29.98	30.02	30.07	30.21	30.00	30.11	30.07	—
Highest temperature, - -	50	51	58	78	84	92	86	86	80	79	62	61	72	—
Lowest temperature, - -	−11	−10	13	21	33	45	46	45	35	25	19	—	22	—
Mean temperature, - -	25	22	31	45	56	67	68	67	59	52	39	31	47	—
Relative humidity, - -	—	—	—	61	64	71	75	75	77	78	—	—	—	—
Total precipitation, - -	3.76	3.97	5.58	2.20	1.17	3.72	5.55	3.27	3.31	1.54	2.10	2.14	—	38.31
Number of days with precipitation of .01 inch or more,	10	8	11	6	8	9	10	4	8	7	4	8	—	93
Number of clear days, - -	11	11	6	18	14	11	12	11	12	7	8	11	—	132
Number of fair days, - -	11	6	13	10	8	13	9	11	9	13	13	15	—	131
Number of cloudy days, -	9	11	12	2	9	6	10	9	9	11	9	5	—	102
Total movement of wind in miles,	7466	7091	8826	7326	5932	5227	5543	3170	5184	4635	5736	5940	—	—
Maximum velocity of wind, -	48	48	55	48	32	32	26	30	36	36	40	38	—	—

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PUBLICATIONS OF THE STATION.

The publications of the Station will be mailed to all citizens of Connecticut, and to Granges, Farmers' Clubs, and other agricultural organizations, who ask for them, and so far as circumstances permit, to those who apply from other States.

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